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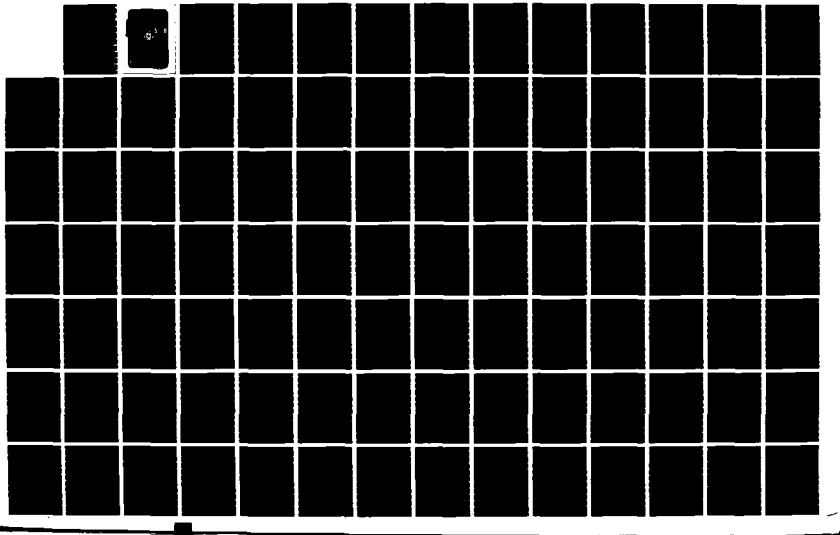

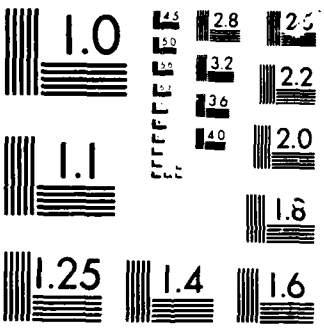
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COMMAND AND CONTROL (C^2) ENHANCEMENTS FOR FORCEM

MAY 1986

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This report describes the approach taken by the U. S. Army Concepts Analysis Agency to validate and enhance the command and control (C^2) decision rules in the Force Evaluation Model (FORCEM) through the structured application of military expertise and statistical analysis.

FORCEM is a fully automated computer model that simulates combat, combat support, and combat services support in a theater. C^2 is treated through a set of decisions, each represented through embedded rules which in turn

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reference preselected information from the perception data base.

In this study, the knowledge of students at the U. S. Army War College is used to validate and enhance the decision rules in FORCEM. Eight of the decisions treated in FORCEM are selected for experimentation. For each decision, an experiment is designed wherein the perception data base variables used in making the decision in FORCEM are controlled and varied. For each case (with a value assigned to each perception data base variable), the subject is asked what the decision should be. Each experiment (one decision, a number of cases) is administered to a group of subjects. Statistical analysis is applied to the results of the experiments.

Regarding findings, information is obtained that can be used to adjust the existing decision rules.

The value in this study is in its combination of the techniques of computer modeling, military expertise, and statistical analysis.

STUDY REPORT
CAA-SR-86-5

COMMAND AND CONTROL (C^2) ENHANCEMENTS FOR FORCEM

May 1986

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CAA	COMMAND AND CONTROL (C^2) ENHANCEMENTS FOR FORCEM	STUDY SUMMARY CAA-SR-86-5

THE REASON FOR PERFORMING THE STUDY is to validate and enhance the rules for command and control (C^2) decisionmaking in the Force Evaluation Model (FORCEM). FORCEM is a fully automated computer model of combat, combat support, and combat service support (CSS) in a theater. C^2 is treated through a set of decisions, each represented through embedded rules which in turn reference preselected information from the perception data base.

THE PRINCIPAL FINDINGS OF THE STUDY are:

(1) The approach used in this study provides a valuable tool for developing or revising decision rules.

(2) The perception data base variables used in the rules currently in FORCEM are relevant to the decisions.

(3) Several additional variables are suggested for incorporation in the FORCEM perception data base, for possible use as criteria for making decisions.

(4) For several decisions, existing perception data base variables are suggested for use as decision criteria, over and above the variables used in the rules currently in FORCEM.

(5) Data are obtained that can be used to adjust the rules currently in FORCEM to better reflect the views of the subjects queried in the study.

(6) The techniques for gathering data for this study yield starting points for methods to record decision processes of gamers for FORGE, an interruptible wargame based on FORCEM. Due to the schedule for development of FORGE, and the constraint on time for this study, no further consideration was given to FORGE.

THE MAIN ASSUMPTION is that FORCEM provides an adequate context for examining C^2 issues at echelons above division.

THE PRINCIPAL LIMITATION is that the study is limited to the "Blue" perspective; i.e., that of the US and its allies.

THE SCOPE OF THE STUDY is the following set of decisions from the FORCEM C^2 module:

(1) Assignment of new corps.

(2) Assignment of new division.

(3) Assignment of new field artillery battalion.

(4) Designation of posture of online corps.

(5) Specification of priority to corps for close air support (CAS).

(6) Specification of priority to corps for CSS.

(7) Specification of priority to division for CAS.

(8) Specification of priority to division for CSS.

THE STUDY OBJECTIVES were to:

(1) Develop and apply methodologies to:

(a) Examine specific decisions using scenarios extracted from FORCEM or FORGE, including selected data from the perception data base and graphics displays,

(b) Prepare and exercise "offline" experiments based on the scenarios, and

(c) Apply the information collected from the experiments to validate and enhance the decision rules in FORCEM, and to design methodologies for use during the actual exercise of FORGE.

(2) Develop methodologies to:

(a) Record gamer decision processes during the exercise of FORGE, and

(b) Use the information collected from gamers to validate and enhance the decision rules in FORCEM.

(3) Make recommendations for actual exercises of FORGE.

THE BASIC APPROACH was to design "offline" experiments based on the selected decisions, administer the experiments to groups of students at the US Army War College, and apply statistical analysis to the results of the experiments. Additional information was collected through a post-experiment questionnaire.

THE STUDY SPONSOR was the Director, US Army Concepts Analysis Agency.

THE STUDY EFFORT was directed by Dr. James J. Metzger, Forces Directorate, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be directed to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FOF, 8120 Woodmont Avenue, Bethesda, MD, 20814-2797.

Tear-out copies of this synopsis are at back cover.

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COMMAND AND CONTROL (C^2) ENHANCEMENTS FOR FORCEM

CHAPTER 1

EXECUTIVE SUMMARY

1-1. PROBLEM. The problem is to validate and enhance the rules for command and control (C^2) decisionmaking in the fully automated Force Evaluation Model (FORCEM) through the structured application of military expertise and statistical analysis.

1-2. BACKGROUND

a. FORCEM is a fully automated computer model that simulates combat, combat support, and combat service support (CSS) in a theater. C^2 decisionmaking is represented at headquarters units at three echelons--theater, army, and corps (in US terminology). C^2 is treated through a set of decisions, each represented through embedded rules which in turn reference preselected information from the perception data base (an internal data base containing information known to headquarters units making the decisions). The user has limited control through the designation of threshold values to which the variables from the perception data base are compared in the rules.

b. The FORCEM Gaming Evaluator (FORGE) is an interruptible wargame based on FORCEM. It allows gamers to make the key decisions at the theater and army echelons. In making such decisions, the gamers have available the information in the perception data base (not just the data used in the rules embedded in FORCEM) plus graphics displays of the battlefield.

c. Military expertise can be brought to bear to validate and enhance the decision rules in FORCEM. This can be accomplished by using "offline" experiments (question sessions using human subjects as decisionmakers) based on FORCEM or FORGE scenarios, or by using FORGE itself.

1-3. PURPOSE AND OBJECTIVES. The purpose of the study is to validate and enhance the decision rules in FORCEM. The objectives are to:

a. Develop and apply methodologies to:

(1) Examine specific decisions using scenarios extracted from FORCEM or FORGE, including selected data from the perception data base and graphics displays,

(2) Prepare and exercise "offline" experiments based on the scenarios, and

(3) Apply the information collected from the experiments to validate and enhance the decision rules in FORCEM, and to design methodologies for use during the actual exercise of FORGE.

b. Develop methodologies to:

(1) Record gamer decision processes during the exercise of FORGE, and

(2) Use the information collected from gamers to validate and enhance the decision rules in FORCEM.

c. Make recommendations for actual exercises of FORGE using the methodologies of paragraph 1-3b above.

1-4. SCOPE. The decisions selected for experimentation are shown in Table 1-1. The numbering of decisions is for reference in this report only.

Table 1-1. FORCEM Decisions Considered in Study

Number	Decision
1	Assignment of New Corps
2	Assignment of New Division
3	Assignment of New Field Artillery Battalion
4	Designation of Posture of Online Corps
5	Specification of Priority to Corps for Close Air Support (CAS)
6	Specification of Priority to Corps for CSS
7	Specification of Priority to Division for CAS
8	Specification of Priority to Division for CSS

1-5. LIMITATIONS. This study is limited to the "Blue" perspective; i.e., that of the US and its allies.

1-6. TIMEFRAME. This is a methodology study; hence timeframe is not critical.

1-7. ASSUMPTION. FORCEM provides an adequate context for examining C^2 issues at echelons above division.

1-8. STUDY APPROACH AND METHODOLOGY. The primary approach is to develop and apply statistical experiments for the decisions shown in Table 1-1. For each such decision, an "offline" experiment is designed wherein the perception data base variables (used in the rules currently in FORCEM) are controlled and varied. For each case (with a value assigned to each perception data base variable), the subject is asked what the decision should be. Each experiment (one decision, a number of cases) is administered to a group of subjects. Statistical analysis is applied to the experimental data to develop mean values and prediction equations, and then to compare the results to the rules currently in FORCEM. Several other approaches providing useful data for the study are described in Chapter 2.

1-9. ESSENTIAL ELEMENTS OF ANALYSIS

a. Are the decisions currently represented in FORCEM appropriate for a theater-level model?

This question is not addressed directly. Each subject considers one (or at most, a few) of the FORCEM decisions, so that a comprehensive view of the full suite of decisions is not possible. However, based on written comments by several subjects, and on opinions gathered previously by the director of this study, the following can be stated: Generally, the major categories of FORCEM decisions--resource allocation, maneuver control, and interface with the other functional areas--are acceptable. Some of the specific decisions are immediately acceptable. For a reader or listener to understand and accept other decisions, however, detailed knowledge of FORCEM is required. This is a consequence of the fact that the need for, and format of, C^2 decisions is driven by the structure of FORCEM; i.e., C^2 must be tied to (and integrate) the representations of the other functional areas. Of the decisions in Table 1-1, all but the first are readily understood, while that one falls into the category of not readily understood without detailed knowledge of FORCEM.

b. For each decision, what are the critical data; i.e., what are the pertinent data items from the perception data base?

Given only the variables from the perception data base that are used in the current rules, the subjects indicate that those variables are essential to the decisions. However, the subjects suggest several variables for use as decision criteria that are not currently in the FORCEM perception data base; these variables are shown in Figure 1-1.

- Rate of loss for friendly forces
- Rate of loss for enemy forces
- Time in sustained combat for friendly forces
- Time in sustained combat for enemy forces
- Geographical momentum
- Projected rate of movement
- Number of divisions that can be placed in area
- Status of artillery support
- Status of CAS
- Control of air
- Enemy posture

Figure 1-1. Additional Perception Data Base Variables

Also, for certain decisions, the subjects suggest the use of existing perception data base variables as decision criteria over and above the variables currently used. Figure 1-2 displays these suggestions, with the format of decision followed by the existing perception data base variables to be added as decision criteria.

- Assignment of new field artillery battalion
  - Posture of potential receiving corps
  - Status of divisional field artillery
- Designation of posture of online corps
  - Terrain
  - Status of associated corps support complex
  - Information on neighboring online corps
- Priority to corps (or division) for CAS
  - Posture of corps (or division)
  - Adequacy of recent CAS support
- Priority to corps (or division) for CAS
  - Posture of corps (or division)
  - Current CSS status of associated corps support complex (or of division and associated division support complex)

Figure 1-2. Expanded Criteria for Decisions

c. Are the decision rules embedded in FORCEM appropriate? If not, how should they be expanded or modified?

For decisions 1, 2, and 3, the results of the experiments do not match the rules currently in FORCEM. The decisions generated by the experimental data differ clearly from those generated by the current rules. This indicates that the rules could be replaced with table lookup procedures based on the experimental data in order to obtain "better" decisions. However, the limited experience of the subjects in decisionmaking at the echelons considered in the experiments, and the lack of knowledge of the subjects about FORCEM itself, argue for great caution in accepting the experimental data as gospel and applying such data in FORCEM. In summary, the experiments for decisions 1, 2, and 3 do not validate the rules currently in FORCEM; but the experiments do not invalidate the rules either.

For decisions 4 through 8, the decisions in FORCEM are already made using table lookup procedures. The data from the experiments can be used in preparing inputs for the tables.

1-10. SUMMARY OF KEY FINDINGS AND RECOMMENDATIONS. Major findings are documented in paragraph 1-9 above. The following are additional findings and recommendations:

a. Findings. The techniques applied in this study--offline experiments with human subjects acting as decisionmakers, followed by statistical analysis--are useful for developing decision rules initially or revising existing rules.

b. Recommendations

(1) For testing purposes, table lookup procedures should be installed in FORCEM for decisions 1, 2, and 3. Then testing should be conducted to assess the reasonableness of the outcomes of the decisions when the data from this study are used.

(2) The primary focus of this study--decision rules in FORCEM--and the approach taken in considering the rules--offline experiments based on the decisions--yield little information regarding the use of FORGE. Furthermore, due to the schedule for development of FORGE, and the constraint on time for this study, no further consideration is given to FORGE. Nevertheless, the following limited suggestion about FORGE can be made: the techniques for gathering data for this study can be adapted to yield methods for recording FORGE gamers' decision processes. After the gamers have completed a cycle of decisionmaking and the simulation is reactivated, the gamers can be queried to ascertain the reasons for their decisions and the relative importance of the reasons.

(3) Whether and how to use FORGE to validate and enhance the decision rules in FORCEM should be topics for future studies.

CHAPTER 2

TECHNICAL APPROACH

2-1. OVERVIEW. The primary approach is to develop and apply statistical experiments for major FORCEM decisions. The design and conduct of the experiments are discussed briefly in paragraph 2-2 and in greater detail in Chapters 4 through 6. Prior to the conduct of the full set of experiments, several pilot experiments are conducted to determine the feasibility of the experimental approach. Material on these pilot experiments is contained in paragraph 2-3 and in Chapter 3. In order to solicit subjects' insights on topics other than simply how the decisions should be made, questionnaires are administered at the completion of experiment sessions (see paragraph 2-4). The Red perspective is addressed to a limited extent through discussions with Soviet experts (see paragraph 2-5).

2-2. EXPERIMENTS

a. Eight FORCEM C^2 decisions are selected for experimentation (see Table 1-1). The decisions are selected because they are important decisions in FORCEM, because they are simple decisions (as opposed to complex constructions combining several other decisions), and because they are amenable to the experimental technique. For each decision, an experiment is designed wherein the perception data base variables (used in the rules currently in FORCEM) are controlled and varied. For each case (with a value assigned to each perception data base variable), the subject is asked what the decision should be. Each experiment (one decision, a number of cases) is administered to a group of subjects from the US Army War College. In order to provide the subjects with background information on FORCEM C^2 and on the significance of the decision under consideration, an information paper is prepared for each experiment and distributed prior to the conduct of the experiment (see Appendix C).

b. For each experiment, mean values (across subjects) are computed. Then analysis of variance is applied to the results to determine what variables are significant, i.e., essential to making the decision. Then regression analysis is applied to obtain an equation for predicting the proper value of the decision based on the values of the significant variables. Then comparisons are made among the decisions made in accordance with the mean values, the prediction equation, and the rules currently in FORCEM. Results and recommendations that follow from these analyses are given in Chapter 7.

2-3. PILOT EXPERIMENTS. To determine the feasibility of the experimental technique described in paragraph 2-2 above, three pilot experiments are conducted at the US Army Concepts Analysis Agency (CAA) prior to the administration of the full set of experiments to subjects outside CAA. Two of the three experiments are successful, and are therefore included as experiments in the study itself. The third is not successful, and is therefore dropped from further consideration. Based on the success of the two

experiments, a "go-ahead" is given to proceed to a full set of experiments for administration to subjects outside CAA. For further details on the pilot experiments, see Chapter 3.

2-4. QUESTIONNAIRES. The experiments and subsequent statistical analysis address the issues of whether the variables from the perception data base that are currently used in the rules in FORCEM are "significant" (i.e., relevant to the decisions), and how they should be used in the decisions. Not addressed is the issue of whether other information should be considered in making the decisions. To solicit this type of information, a questionnaire is prepared by the US Army Research Institute for the Behavioral and Social Sciences (ARI) for completion by subjects after the experiments. A copy of the questionnaire is contained in Appendix D. The written responses of subjects are compiled in Appendix E. A summary by ARI of quantitative responses to the questionnaire is given in Appendix F. Useful information gleaned from the questionnaire is of two kinds: additional information that should be available for use in C^2 decisionmaking that is not currently available (i.e., candidate data for incorporation into the perception data base), and additional data that should be used in making specific decisions (i.e., existing perception data base variables that should be used in the rules in FORCEM to augment the variables already used). Further information on these two types of data can be found in Chapter 7 and Appendices K and L.

2-5. DISCUSSIONS. To ascertain the extent to which FORCEM decisions and the current decision rules reflect Soviet thinking, discussions are held with experts in Soviet doctrine and tactics. The resulting observations and suggestions are incorporated into Appendix J.

CHAPTER 3

PILOT EXPERIMENTS

3-1. INTRODUCTION

a. Prior to embarking on a large data collection effort, three pilot experiments are conducted at CAA to determine the feasibility of the experimental technique. The decisions on which the pilot experiments are based are: assignment of a new corps (Table 1-1, decision 1), designation of posture of online corps (Table 1-1, decision 4), and designation of corps type of operation (not shown in Table 1-1). The experiments for decisions 1 and 4 are successful. The experiment for the decision on corps type of operation shows that the information about the meaning and use of this model variable that can be provided to the subjects is insufficient to permit them to discriminate among the (eight) values of the variable and thereby to select the value sensibly. Consequently, the decision on corps type of operation is excluded from consideration for experimentation in the study.

b. The results obtained for decisions 1 and 4 are sufficiently encouraging to warrant proceeding to a full set of experiments for administration to subjects outside CAA.

c. For illustrative purposes, this chapter describes the pilot test for decision 1. This test involves designing the experiment, conducting the experiment, performing statistical analysis to develop a prediction equation, comparing the predicted values with the mean values of the experimental data and with the results of the rules currently in FORCEM, and testing the prediction equation in FORCEM itself.

3-2. DESIGN. As currently coded in FORCEM, the decision on assignment of a new corps involves placing it in reserve status behind an online corps (for possible later commitment to assist that online corps or one of its neighboring online corps), and is accomplished by ranking the potential receiving online corps according to need and then selecting the one with greatest need. This experiment addresses the process of determining the rank (i.e., need) of a potential receiving online corps. The rules used in determining the rank of a potential receiving online corps utilize five perception data variables, combined for this experiment into the four factors A, B, C, and D shown below. Explanations of the perception data base variables are given in the first information paper in Appendix C.

A: Whether given online corps already has a reserve corps behind it.

B: Engagement status of given online corps.

C: Friendly-to-enemy force ratio faced by given online corps.

D: Combination of --

- Location of objective of online corps relative to location of corps (objective is "forward," "reached," or "to rear" of corps; i.e., corps is to move forward, hold, or move to rear).
- Posture of given online corps (attack, defend, delay, withdraw).

Of the combinations of location and posture for factor D, only the six shown in Table 3-1 are possible.

Table 3-1. Possible Location/Posture Combinations

Objective location	Posture			
	Withdraw	Delay	Defend	Attack
Rear	1			
Reached		2	3	
Forward		4	5	6

The levels considered for the four factors A, B, C, and D are shown in Table 3-2. Each of the factors is crossed with each of the other factors. Consequently, the basic experiment has a 2x2x2x6 factorial design with 48 cells.

Table 3-2. Levels of Decision Factors

Factor	Levels					
	1	2	3	4	5	6
A	No res	Has res				
B	Not eng	Engaged				
C	1:3	3:1				
D	Rear/ Withdraw	Reached/ Delay	Reached/ Defend	Forward/ Delay	Forward/ Defend	Forward/ Attack

Administering the experiment involves asking a subject to specify a "criticality index" (from 0 to 100) for a particular combination of factors. This criticality index indicates the need of the potential receiving online corps. A sample question is shown in Appendix G, Figure G-1. In order to assess the variability of subject, the variable T, Subject, is also treated as a factor. This gives the four "fixed" factors A, B, C, and D, and the one "random" factor T. Five of the 48 cells are replicated to provide an estimate of residual variability.

3-3. CONDUCT OF EXPERIMENT. Nine field grade officers on duty at CAA are selected as subjects. Each subject is asked the full set of 53 questions (48 cells plus 5 replicates). A sample question is shown in Appendix G, Figure G-1.

3-4. STATISTICAL ANALYSIS

a. First of all, the data are averaged over all subjects to obtain mean values for the 48 cells. The resulting cell means are shown in Appendix G, Table G-1. The marginal means are shown in Appendix G, Table G-2. An examination of Table G-2 indicates that the largest effect of the three two-level factors is C (force ratio).

b. The next step is analysis of variance (ANOVA). The ANOVA model is

$$y_1 = \hat{\mu} + A + B + C + D + T + AB + AC + \cdots + DT + \cdots + ABCDT + \text{Residual} \qquad (3\text{-}1)$$

where y_1 represents criticality index, $\hat{\mu}$ is an unknown constant; A, B, C, D, and T are as defined above. The ANOVA table is given in Appendix G, Table G-3. Main effects and interaction effects that are significant at the 0.05 and 0.01 levels of significance are identified. Even though many of the subject interactions are significant, tests of the fixed factors' effects are sufficiently powerful to detect significant main effects and interaction effects. All four main effects A, B, C, and D are statistically significant, as are two interaction effects AC and CD. This yields

$$(y_1)_{ijkm} = \hat{\mu} + A_i + B_j + C_k + D_m + A_iC_k + C_kD_m \qquad (3\text{-}2)$$

as a candidate model for a prediction equation. Regression analysis with dummy variables is used to develop the following prediction equation:

$$\begin{aligned} y_1 = {} & 34.3 - (19.6)(A) + (6.9)(B) - (20.1)(C) - (3.6)(D_1) \\ & + (3.9)(D_2) + (13.2)(D_3) + (48.4)(D_4) \\ & + (9.9)(D_5) + (7.8)(A)(C) + (3.9)(C)(D_1) \\ & - (2.6)(C)(D_3) - (37.6)(C)(D_4) - (8.2)(C)(D_5) \end{aligned} \qquad (3\text{-}3)$$

where A = 1 if given online corps already has a corps in reserve behind it
= 0 if given online corps has 0 corps in reserve

B = 1 if given online corps is engaged
= 0 if given online corps is not engaged

C = 1 if force ratio is 3:1
= 0 if force ratio is 1:3

D_1 = 1 if location/posture is rear/withdraw
= 0 otherwise

D_2 = 1 if posture is delay
= 0 otherwise

D_3 = 1 if posture is defend
= 0 otherwise

D_4 = 1 if posture is attack
= 0 otherwise

D_5 = 1 if location is forward
= 0 otherwise

c. The factor D is treated using the five variables D_1 through D_5, rather than through a family of variables that reference the levels for D shown in Table 3-1, in order to allow segregation of the contributions of location and posture.

d. Equation (3-3) is used to compute predicted "criticality values" for each of the 48 cells. Table G-4 shows the predicted criticality values and associated ranking by need, cell means and associated ranking by need, and ranking by need per the rules currently in FORCEM. Note that the ranking generated by equation (3-3) agrees well with the ranking from the cell means, but does not match the ranking specified by the rules currently in FORCEM. One explanation for the latter discrepancy can be seen by inspection of Table G-4. The driving factor in equation (3-3) is D_4 (whether or not the online corps has a posture of attack); on the other hand, the driving factor for the rules currently in FORCEM is A (whether or not the online corps already has a reserve corps behind it).

3-5. PROTOTYPE IMPLEMENTATION

a. As noted above, the ranking generated by the prediction equation (3-3) (equivalently, by the cell means), does not match the ranking from the rules currently in FORCEM. The next question is whether, in the situations that occur in actual execution of FORCEM, the differences in ranking yield different assignments of new corps. That is--"So What!"

b. As a test, code is installed in FORCEM to permit comparison of the two methodologies for assigning a new corps to reserve status behind a selected online corps based on the ranking (by need) of the potential receiving online corps--

(1) According to the rules currently in FORCEM.

(2) According to equation (3-3).

c. Rather than simply comparing the final selection of the online corps to receive the new corps, the approach taken here is to compare the complete ranking of all potential receiving online corps.

d. A sample situation is shown in Appendix G, Table G-5. There are 15 potential receiving online corps. The ranking values for both approaches are taken from Table G-4. In the displayed situation, and in the other situations where this decision is examined in this prototype implementation, the rankings generated by the two methodologies match, in the sense that their orderings are the same. This would not be the case, however, were some of the potential receiving online corps to have postures of defend or have unfavorable force ratios.

e. Thus the results of this prototype test are inconclusive.

3-6. CONCLUSION. For decision 1, the 14-term prediction equation (3-3) resulting from the ANOVA and regression analysis provides an adequate fit to the cell means data. A similar conclusion can be drawn about decision 4, considered in the second pilot experiment. These pilot experiments are considered successful. A "go-ahead" is given to proceed to a full set of experiments for administration to subjects outside CAA. Decisions 1 and 4 are included in that set of experiments.

CHAPTER 4

EXPERIMENTAL DESIGN

4-1. INTRODUCTION. This chapter describes the design for the experiments for the FORCEM decisions considered for the study. These decisions are shown in Table 4-1, repeated here from Table 1-1 for the convenience of the reader.

Table 4-1. FORCEM Decisions Considered in Study

Number	Decision
1	Assignment of New Corps
2	Assignment of New Division
3	Assignment of New Field Artillery Battalion
4	Designation of Posture of Online Corps
5	Specification of Priority to Corps for CAS
6	Specification of Priority to Corps for CSS
7	Specification of Priority to Division for CAS
8	Specification of Priority to Division for CSS

4-2. DESIGN. The factors considered for each experiment are the perception data base variables used in the rules currently in FORCEM for making the corresponding decision.

The factors used in the experiments are shown in Table 4-2. Interpretations of these factors are provided in the information papers in Appendix C.

Table 4-2. Decision Factors

Symbol	Interpretation
A	Has reserve corps
B	Corps engagement status
C	Corps force ratio
D	Location of objective of corps/posture of corps
E	Echelon to which corps assigned/has reserve corps
F	Echelon to which corps assigned
G	Ratio of corps artillery battalions to divisions
M	Location of objective of corps
N	Posture of parent army
P	Division engagement status
R	Division force ratio
S	Echelon to which division assigned

The levels for each factor are selected in order to provide a realistic range while keeping the total number of cells for a given experiment manageable. The levels are displayed in Table 4-3. For any factor appearing in several experiments, the levels used are the same. Note that three levels are chosen for factor C, rather than the two levels used in the pilot experiment described in Chapter 3.

Table 4-3. Levels of Decision Factors

Factor	Level					
	1	2	3	4	5	6
A	No res	Has res				
B	No res	Engaged				
C	1:3	1:1	3:1			
D	Rear/ Withdr	Reached/ Delay	Reached/ Defend	Fwd/ Delay	Fwd/ Defend	Fwd/ Attack
E	Reserv	Onln/Yes	Onln/No			
F	Reserv	Online				
G	1.00	0.25				
M	Rear	Reached	Forward			
N	Delay	Defend	Attack			
P	No	Yes				
R	1:3	1:1	3:1			
S	First	Second	Third			

All the factors within each experiment are completely crossed with all other factors of the experiment. Consequently, all designs are factorial designs. The factors and numbers of cells are shown in Table 4-4. In order to estimate the residual (i.e., error variance), several cells are replicated for each experiment; e.g., for decision 1, there are 72 cells in the basic design plus 4 replicates. The replication of cells permits the estimation of residual, albeit a less reliable estimate than that afforded by replication of all cells.

Table 4-4. Factors in Experiments

Decision number	Factors	Number of levels	Number of cells
1	AxBxCxD	2x2x3x6	72
2	BxCxDxE	2x3x6x3	108
3	BxDxFxG	2x6x2x2	48
4	CxMxN	3x3x3	27
5	BxCxF	2x3x2	12
6	BxCxF	2x3x2	12
7	PxRxS	2x3x3	18
8	PxRxS	2x3x3	13

CHAPTER 5

DATA COLLECTION

5-1. INTRODUCTION

a. Each experiment shown in Table 4-1 is administered to a group of subjects from the US Army War College. The experiments were administered on four afternoons of December 2 and 5, 1985 and January 8 and 10, 1986. Each afternoon consists of two sessions, two hours each, at which approximately 10 subjects are administered several of the eight decisions in succession, and then the questionnaire (Appendix D) prepared by US Army Research Institute for the Behavioral and Social Sciences (ARI). The various cases of a particular experiment are presented to a subject on a VAX 11/780 terminal. Each case so presented consists of a unique set of levels of each factor involved in the experiment. For instance, in experiment 1 (Assignment of New Corps), the subject is presented with a unique case involving an online corps. The subject is told that the online corps: (1) has no corps in reserve behind it (level 1 of factor A; see Tables 4-2 and 4-3); (2) is engaged (level 2 of factor B); (3) has a friendly-to-enemy force ratio of 1:1 (level 2 of factor C); and (4) is defending and has reached the location of the parent army's objective (level 3 of factor D). This unique case is denoted as the four-tuple (1, 2, 2, 3), or 1223 for short. For experiment 1, there are 72 cases formed by selecting one level of each of the four factors. All 72 cases are presented to each subject. Each such case is called a cell in statistical terminology. Each experiment is replicated by administering it to a number of different subjects. The available subjects are divided into eight groups. Table 5-1 shows the allocation of experiments (decisions 1 through 8) to subject groups (a through h). The subjects are assumed to be a random sample from a population well versed in making combat decisions of this kind.

Table 5-1. Allocation of Subjects to Experiments

Group	Decision								Number of subjects
	1	2	3	4	5	6	7	8	
A	X			X		X			10
B	X			X			X		10
C		X		X	X				10
D		X		X					10
E			X	X				X	10
F			X	X					10
G				X			X	X	10
H				X	X	X			11

Each of experiments 1, 2, 3, 7, and 8 is administered to 20 subjects. Each of experiments 5 and 6 is administered to 21 subjects. Experiment 4 is administered to all 81 subjects. Since these experiments involve repetitious operations, the order of cell presentation may be important, either because a learning process is involved which tends to make later responses better than earlier ones, or because fatigue tends in the opposite direction. Randomization is a statistical technique which is applied to the order of presentation of the cells in order to avoid possible biases that might favor or handicap a particular cell affected by some extraneous source of variation correlated with the fixed order of presentation. Each subject is presented with a different random ordering of the presentation of cells. In order to give the subject experience prior to the actual conduct of an experiment, the subject is presented with 3 to 5 sample cells which do not count. Also for each of experiments 1, 2, 3, 5, 6, 7, and 8, four of the cells are picked at random in the preparation stage of the experiment, and are given twice during the experiment for a measure of within-subject variation. These replications are used in subsequent analysis to measure random error. The four replicated cells for each experiment are incorporated into the order randomization scheme for the nonreplicated cells as described above.

b. Lastly, Table 5-2 summarizes the background of the subjects by rank and branch affiliation.

Table 5-2. Subject Background

Branch or service	Rank		Other	Total
	COL	LTC		
AD	2	3		5
AG	0	1		1
AR	1	13		14
AV	0	3		3
CE	1	0		1
CM	0	1		1
DC	1	0		1
EN	1	5		6
FA	3	9		12
FI	0	1		1
IN	2	12		14
MI	1	3		4
MP	1	1		2
MS	1	0		1
OD	0	3		3
QM	0	1		1
SC	0	3		3
TC	1	0		1
USAF	1	1		2
Civilian & other			5	5
Total	16	60	5	81

5-2. DATA

a. The raw data for experiments 1, 2, 3, 5, 6, 7, and 8 are tabulated in Appendix H, Tables H-1 through H-7. The first column of each of these tables is an n-tuple that identifies the cell by indicating the level of each of the factors that make up the cell. For example, in Table H-1, the four-tuple 1223 (the 27th entry from the top in the first column) indicates the cell: (1) no corps in reserve (level 1 of factor A; see Table 4-2 and Table 4-3); (2) is engaged (level 2 of factor B); (3) has a friendly-to-enemy force ratio of 1:1 (level 2 of factor C); and (4) is defending with the objective location as reached (level 3 of factor D). Each entry in a row from the second column to the twenty-first (experiments 1, 2, 3, 7, and 8) or the twenty-second (experiments 5 and 6) is the criticality response given by an individual subject to the cell labeled in column one. The next to last column of each row is the mean of the row, and the last column is the standard deviation of the row. Following the main body of the table are two spaced rows with no n-tuple. The first row is the mean response for each subject. The second row is the standard deviation for each subject. Following these two summary rows are the replication data in the same format as the main body of the table.

b. The raw data for experiment 4 are tabulated in Appendix H, Table H-8. In experiment 4, the subject is asked to respond to a particular cell description of the experiment by designating one of the four postures attack, defend, delay, or withdraw. All 81 subjects are given experiment 4. The three-tuple identifies the levels of factors C, M, and N (see Table 4-1 and Table 4-2) for the row. The second through fifth columns give the number of subjects responding with the posture indicated by the label above the column. The three columns at the right describe the cell in FORCEM terminology.

CHAPTER 6

STATISTICAL ANALYSIS

6-1. INTRODUCTION. This chapter describes the statistical analysis performed on the data collected from the experiments. Two basic approaches are applied to the decisions listed in Table 4-1. The first approach--applied to decisions 1, 2, 3, 5, 6, 7, and 8--is treated in paragraph 6-2. Supporting data are shown in Appendix I. The second approach--applied to decision 4--is treated in paragraph 6-3.

6-2. FIRST APPROACH. Decisions 1, 2, 3, 5, 6, 7, and 8 are treated with the same approach--ANOVA followed by regression analysis. The first step for each decision is an ANOVA of the experiment as designed per Chapter 4. This yields an additive model, referred to as the ANOVA model. It allows the sum of squares to be partitioned into terms representing main effects, interactions, and error components. Each of the effect mean squares may then be divided by the error mean square to yield a ratio that--under the assumptions of the ANOVA model and the null hypothesis--is distributed as F (i.e., Fisher distribution) with appropriate degrees of freedom. The main advantage of the ANOVA model is that it permits determining which effects and which interactions account for a significant amount of the variation in the data. On the other hand, the ANOVA model is usually overparameterized and hence unwieldy for use as a prediction model. Frequently, the information in the ANOVA model can be adequately captured, and more parsimoniously expressed, in a regression equation. This is particularly true when most of the variation is accounted for in the main effects and a few lower-order interaction terms. Regarding the decisions considered here, another advantage of a regression model is that it allows naturally continuous variables (e.g., C and G of Table 4-2) to be treated as continuous. For these reasons, the second step in the statistical analysis of each of the decisions 1, 2, 3, 5, 6, 7, and 8 is to develop a prediction equation using regression analysis. The final step is to compare the values given by the rules currently in FORCEM with those predicted by the cell means and with those predicted by the regression equation.

a. To illustrate this approach, the treatment of decision 1 (Assignment of New Corps) is now discussed in detail. For the other decisions, results are shown later in this chapter, and details are provided in Appendix I. The ANOVA model for decision 1 is

$$y_1 = \hat{\mu} + A + B + C + D + T + AB + AC + \ldots + DT + \ldots + ABCDT + \text{Residual} \qquad (6\text{-}1)$$

Where y_1 represents the criticality (value between 0 and 100) of assigning the new corps to reserve status behind the given online corps; $\hat{\mu}$ is an unknown constant; A, B, C, and D are the fixed factors described in Table 4-2 with the levels shown in Table 4-3; and T is the random factor containing the subject effect. First of all, the experimental data are averaged

across all subjects to obtain cell means; these are displayed in Appendix I, Table I-4. The marginal means are shown in Appendix I, Table I-5. Then ANOVA is applied; the ANOVA table for the experimental data is displayed in Appendix I, Table I-6. Of primary interest in this table are the main effects and their interactions. However, in order to explain the ANOVA table it is best to begin at the bottom and move upward. The component of the table labeled "Error" relates to random error within subject. As noted in Chapter 4, four of the questions are replicated for this experiment in order to estimate the residual (i.e., error variance). The mean square error term of the error component is used to test each of the other random effects (i.e., factor T and every higher-order interaction term containing T). Dividing each such mean square term by the corresponding error mean square term yields a ratio that is distributed as F under the null hypothesis (e.g., $\sigma_T^2 = 0$, $\sigma_{AT}^2 = 0$). As indicated in Table I-6, many random components are significant. Whether this is due to an unreliable error estimate, or to random components that are truly significant, cannot be determined. Because the primary focus here is the fixed effects, and because the variation in the random components does not overwhelm the variation in the fixed effects, the significance of the random components need not be considered further. Each fixed effect's mean square error is tested against the variance component's mean square error; e.g., A is tested against AT; ABCD is tested against ABCDT. Under the null hypothesis one expects no level effect for a particular factor or factor interaction term. Under the null hypothesis and the assumptions of normal, independent and identically-distributed error, the ratio of mean square error associated with a particular factor or factor interaction to the mean square error is distributed as F with m degrees of freedom associated with the particular factor or factor interaction mean square and n degrees of freedom associated with the mean square error. To reject the null hypothesis, and say that there is at least one significant difference due to the particular factor or factor interaction, the ratio of means squares (F-ratio) must be greater than the value of the F distribution with m and n degrees of freedom at some chosen level significance α. The data of this experiment do not adhere strictly to the assumptions, but the ANOVA model is somewhat robust. The main problem of violation occurs with distribution of the responses and probably with inequality of variance. Provided that such violations can be ignored, the primary conclusions to be drawn are that only the main effects A, B, C, and D, and the two higher-order interactions AC and CD, are significant at the alpha = 0.01-level. Two other interaction, AB and ACD are significant at the alpha = 0.05-level.

b. If FORCEM is to apply a table lookup procedure to make the decision, then the cell means can be used directly. If, however, FORCEM is to employ an equation to make the decision, then a regression equation yields a more tractable model. Essentially, the regression model seeks to find a "subspace" of the fixed effects in the ANOVA model that fits the cell means without appreciable error. The ANOVA table itself provides insight into the feasibility of finding this subspace. If none or a few of the higher-order interaction terms are significant, it is likely that a regression equation can be obtained with a reasonable number of terms that matches the ANOVA model without appreciable error. For decision 1, this is the case. The procedure used to develop the model is known as stepwise regr ssion.

The prediction equation yielded by this approach has the form

$$y_1 = \hat{\mu}_1 + (a_{1,1})(A) + (a_{1,2})(B) + (a_{1,3})(LC) + (a_{1,4})(W) + (a_{1,5})(FWD) + (a_{1,6})(ATT) + (a_{1,7})(DEL)(RCH) + (a_{1,8})(A)(LC) + (a_{1,9})(FWD)(LC^2) \quad (6\text{-}2)$$

This equation is repeated in the summary Figure 6-1. The variables y_1, A, ATT, B, DEL, FWD, LC, RCH, and W are defined in Figure 6-2; and the coefficients $\hat{\mu}_1$, $a_{1,1}$, etc, are given in Table 6-1. Note that the factor D is treated using the five variables ATT, DEL, FWD, RCH, and W, rather than through a family of functions that vary with the six levels shown in Table 4-3, in order to allow segregation of the contributions of location and posture.

c. R^2, the "coefficient of multiple determination," is a measure of the variability accounted for by the model, and has a value between 0 and 1. For the ANOVA model of decision 1, the value is 0.452. For the regression model of equation 6-2, R^2 is 0.436. The ratio of these two values is 0.96 out of a possible 1.00, indicating that the regression model matches the ANOVA model well. Another measure of the adequacy of the regression model is Mallows C_p. For equation (6-2), p (the number of terms) is 10, and C_p is -12. Since a value of C_p less than p indicates an adequate model, equation (6-2) suffices. Note that this equation requires only 10 terms to express the 72 degrees of freedom of the ANOVA model. Regarding factor C and the variable LC, caution is in order for extrapolation beyond the limits of the design; i.e., force ratio between 1:3 and 3:1. Nevertheless, extrapolation of C to the range 1:6 to 6:1 seems to be within reason and should not adversely affect the performance of the model.

d. Appendix I, Table I-7 displays comparisons of the criticality index and associated ranking by need--for the regression equation, the cell means, and current FORCEM rules. To the far right, the factor levels are presented in FORCEM terminology. The ranking by need generated by the cell means matches with that generated by the regression equation. Not so for the ranking generated by the current rules when compared with that generated by the cell means. Figure I-1 is a scatter plot comparing these two approaches. The diagonal line represents perfect agreement. The two approaches are clearly different; hence the experiment does not validate the current rules.

e. From equation (6-2) and Table 6-1, it can be concluded that the terms in equation (6-2) involving LC (hence, force ratio) appear with signs indicating the subjects favor reinforcing an online corps with a poor force ratio over one with a good force ratio. This may be due to the fact that the subjects have the Blue perspective; i.e., "reinforce weakness."

f. Decisions 2, 3, 5, 6, 7, and 8 are analyzed in the same manner as described for decision 1 above. The forms of the prediction equations resulting from the ANOVA and regression analysis are shown in Figure 6-1. The associated variables are described in Figure 6-2; and the associated

coefficients are given in Table 6-1. The information for decision 1 is repeated in Figure 6-1 for completeness. Explanations of the decisions made and the decision criteria used are given in Appendix C. Supporting data--cell means, marginal means, ANOVA tables, and comparisons of models--are contained in Appendix I. Also in Appendix I (Table I-3), measures are given of the parsimony of the regression model, adequacy of the regression model, percentage variation explained by the regression model, percentage variation explained by the fixed effects, and the ratio of those two percentages. Specialized comments are now given for certain of the decisions.

Decision 1 -- Assignment of New Corps

$$y_1 = 1 + (a_{1,1})(A) + (a_{1,2})(B) + (a_{1,3})(LC)$$
$$- (a_{1,4})(W) + (a_{1,5})(FWD) + (a_{1,6})(ATT)$$
$$- (a_{1,7})(DEL)(RCH) + (a_{1,8})(A)(LC) + (a_{1,9})(FWD)(LC^2)$$

Decision 2 -- Assignment of New Division

$$y_2 = 2 + (a_{2,1})(B) + (a_{2,2})(LC) + (a_{2,3})(LC^2)$$
$$+ (a_{2,4})(W) + (a_{2,5})(ATT) + (a_{2,6})(DEL)$$
$$+ (a_{2,7})(DEL)(FWD) + (a_{2,8})(ONL)(1-A)$$
$$+ (a_{2,9})(B)(LC^2) + (a_{2,10})(W)(LC^2)$$
$$+ (a_{2,11})(DEL)(LC^2) + (a_{2,12})(ONL)(1-A)(LC^2)$$
$$+ (a_{2,13})(B)(FWD)(LC) + (a_{2,14})(B)(ATT)(LC)$$
$$+ (a_{2,15})(B)(A)(LC) + (a_{2,16})(B)(1-A)(LC)$$
$$+ (a_{2,17})(FWD)(ONL)(1-A)(LC) + (a_{2,18})(ATT)(ONL)(A)(LC)$$
$$+ (a_{2,19})(DEL)(FWD)(1-ONL)(LC) + (a_{2,20})(B)(W)(ONL)(A)(LC)$$
$$+ (a_{2,21})(B)(W)(ONL)(1-A)(LC) + (a_{2,22})(B)(FWD)(ONL)(A)(LC)$$
$$+ (a_{2,23})(B)(FWD)(ONL)(A)(LC) + (a_{2,24})(B)(FWD)(ONL)(1-A)(LC)$$
$$+ (a_{2,25})(B)(ATT)(ONL)(A)(LC) + (a_{2,26})(B)(DEL)(A)(LC)$$
$$+ (a_{2,27})(B)(DEL)(FWD)(ONL)(1-A)(LC)$$

Figure 6-1. Prediction Equations (page 1 of 2 pages)

Decision 3 -- Assignment of New Field Artillery Battalion

$$y_3 = 3 + (a_{3,1})(B) + (a_{3,2})(ONL) + (a_{3,3})(G) + (a_{3,4})(W) + (a_{3,5})(ATT) + (a_{3,6})(ONL)(B)(FWD)$$

Decision 5 -- Specification of Priority to Corps for CAS

$$y_5 = 5 + (a_{5,1})(B) + (a_{5,2})(ONL) + (a_{5,3})(LC) + (a_{5,4})(B)(LC)$$

Decision 6 -- Specification of Priority to Corps for CSS

$$y_6 = 6 + (a_{6,1})(B) + (a_{6,2})(ONL) + (a_{6,3})(LC)$$

Decision 7 -- Specification of Priority to Division for CAS

$$y_7 = 7 + (a_{7,1})(B) + (a_{7,2})(FE) + (a_{7,2})(SE) + (a_{7,4})(LC) + (a_{7,5})(B)(LC)$$

Decision 8 -- Specification of Priority to Division for CSS

$$y_8 = 8 + (a_{8,1})(B) + (a_{8,2})(FE) + (a_{8,3})(LC)$$

Figure 6-1. Prediction Equations
(page 2 of 2 pages)

y_i = output of decision; i.e., for decisions 1 to 3, it is the criticality index for assigning a new unit; for decision 4, it is posture; for decisions 5 through 8, it is priority for CAS or CSS

A = 1 if given online corps already has a corps in reserve behind it
= 0 is given online corps has 0 corps in reserve

ATT = 1 if posture is attack (and location is forward; see Table 4-2)
= 0 otherwise

B = 1 if given online corps is engaged
= 0 if given online orps is not engaged

DEL = 1 if posture is delay (and location is reached or forward; see Table 4-2)
= 0 otherwise

FE = 1 if division is assigned to first echelon
= 0 otherwise

FWD = 1 if location is forward (and posture is delay, defend, or attack; see Table 4-2)
= 0 otherwise

G = Ratio of number of corps artillery battalions to number of divisions

LC = Ln (force ratio); i.e., natural logarithm of friendly-to-enemy force ratio faced by given online corps

ONL = 1 if corps is online
= 0 if corps is reserve

RCH = 1 if location is reach (and posture is delay or defend; see Table 4-2)
= 0 otherwise

SE = 1 if division is assigned to second echelon
= 0 otherwise

W = 1 if posture is withdraw (and location is rear; see Table 4-2)
= 0 otherwise

Figure 6-2. Variables in Prediction Equations

Table 6-1. Coefficients for Regression Equations
(page 1 of 2 pages)

Variables	Coefficents
Decision 1	
$\hat{\mu}_1$	39.23472
LC	-14.97740
ATT	25.78958
A	-16.96389
FWD	7.21597
FWD·LC^2	-5.12850
B	3.87778
A·LC	3.87235
W	-8.16667
DEL·RCH	-5.93333
Decision 2	
$\hat{\mu}_2$	31.86248
B	16.75298
LC	-12.03014
LC^2	-4.67250
W	-17.44812
ATT	30.45287
DEL	-9.95638
DEL·FWD	-4.64445
ONL·(1-A)	13.92714
B·LC^2	-12.08464
W·LC^2	10.25807
DEL·LC^2	5.61111
ONL·(1-A)·LC^2	-5.68261
B·FWD·LC	21.61054
B·ATT·LC	7.09994
B·A·LC	19.42599
B·(1-A)·LC	21.72436
FWD·ONL·(1-A)·LC	22.22505
ATT·ONL·A·LC	23.45383
DEL·FWD·(1-ONL)·LC	-27.39868
B·W·ONL·A·LC	-16.06599
B·W·ONL·(1-A)·LC	-26.30630
B·FWD·ONL·A·LC	-18.48161
B·FWD·ONL·(1-A)·LC	-44.35901
B·ATT·OL·A·LC	-24.71679
B·DEL·A·LC	-22.11916
B·DEL·FWD·ONL·(1-A)·LC	30.83486

Table 6-1. Coefficients for Regression Equations
(page 2 of 2 pages)

Variables	Coefficents
Decision 3	
$\hat{\mu}_3$	50.35625
B	26.45208
G	-14.60000
ONL	11.46042
ATT	7.79375
W	-6.27500
ONL·B·FWD	-6.37500
Decision 5	
$\hat{\mu}_5$	12.35714
B	38.52381
B·LC	-8.14890
ONL	14.93651
LC	-4.75714
Decision 6	
$\hat{\mu}_6$	31.12698
B	25.74603
ONL	18.04762
LC	-7.73712
Decision 7	
$\hat{\mu}_7$	15.28887
B	35.18889
LC	-3.82305
SE	9.36667
FE	22.61667
B·LC	-10.74094
Decision 8	
$\hat{\mu}_3$	32.67083
3	31.3500
LC	-7.58541
FE	13.53750

(1) Decision 2. The ANOVA table (Table I-10) indicates that many of the random effects are quite significant when tested against the partial replicate error. However, many of the fixed effects (main and higher-order interaction terms) are significantly different from zero. The third-order interaction term BCDE is highly significant. This is a tipoff to problems in finding a parsimonious regression equation. In order to assure an adequate model, 27 terms are required in the regression equation as measured by Mallows C_p statistic. However, in the model comparison table (Table I-11), the difference in the criticality index predicted by the regression equation and the cell mean is quite large for a few cells. The largest absolute difference between the regression equation and a cell mean is 13.6 located at priority number 13 for the regression model. This is still a sizable difference, even though the regression model is adequate. Furthermore, 27 terms is 25 percent of the terms represented by the cells or the fixed effects and interactions in the ANOVA model. This is hardly parsimonious. For these reasons, it is best for this decision that the cell means be used in a table lookup procedure rather than incorporating the regression equation into FORCEM. Regarding the validity of the current rules, Figure I-2 is a scatter plot of ranking by need generated by the current rules versus that generated by the cell means. As with decision 1, the two approaches are clearly different.

(2) Decision 3. Corps posture is included in this experiment (as part of factor D) but not in the rules currently in FORCEM. However, the experiment shows (see Table I-14) that posture is significant; i.e., it should be considered in making the decision. Also, because the Mallows C_p for this experiment is greater than p (see Table I-3), the regression equation is not a fully satisfactory representation of the cell means; hence, a table lookup procedure using cell means is the preferred method of implementation. Regarding the validity of the current rules, Figure I-3 is a scatter plot of ranking by need generated by the current rules versus that generated by the cell means. As with decision 1, the two approaches are clearly different.

(3) Decisions 4 through 8. The rules currently in FORCEM already use lookup procedures based on input tables. Hence there is no need to compare the current rules with the experimental data.

(4) Decisions 5 through 8. For each such decision, the subject is asked to specify the priority for support (the y_i of Figures 6-1 and 6-2), where a higher value indicates higher priority. On the other hand, within FORCEM the priority is used quantitatively; it has positive integer values (not restricted to being less than 100); and a smaller value means higher priority. For these reasons, neither the cell means nor the prediction equations for these decisions can be used directly. The information contained in the equations, however, is of use, as is noted in paragraph 6-2g below. Lastly, note (from equation (6-2) and Table 6-1) that all terms involving LC appear preceded by a minus sign, indicating (as for decision 1) that the subjects favor a unit with a poor force ratio over one with a good force ratio.

g. Information on the relative importances of the factors (i.e, decision variables) as perceived by the subjects can be of use to those who apply FORCEM, especially for decisions 5 through 8 where the regression equations cannot be used directly. For most of the regression equations in Figure 6-1, the presence of interaction terms makes it impossible to assess relative importances. Decisions 6 and 8 are fortunate exceptions; the relative importances of the factors for these decisions can be determined and are shown in Figure 6-3. For decision 5, engagement status is preeminent, but the relationship between assigned echelon and force ratio is less clear. Decision 7 is even less amenable to this type of analysis.

- Decision 6--Specification of priority to corps for CSS
  - Engagement status
  - Online or reserve
  - Force ratio
- Decision 8--Specification of priority to division for CSS
  - Engagement status
  - Assigned echelon
  - Force ratio

Figure 6-3. Relative Importance of Decision Criteria

6-3. SECOND APPROACH. Decision 4, Designation of Posture of Online Corps, must be treated differently from the other decisions because it involves an order categorical response variable. The response variable is posture. The subject is required to choose the most appropriate posture for a given set of input factors. The choice is attack, defend, delay, or withdraw. The factors take on the same character as in the first approach giving a structure on which to base the experiment. The factors C, M, and N are described in Table 4-2, and the levels are shown in Table 4-3. In FORCEM, a definite posture must be assigned to a corps given a set of factor levels. This is a deterministic choice versus a stochastic choice as in most analytic modeling techniques. An approach to dealing with this statistically is to test each cell with a simple statistical hypothesis test. For each of the 27 cells, the null hypothesis for the cell is that less than half of the expert population chooses any one of the postures. The alternate hypothesis, the statement desired for the cell, is that more than half of the expert population chooses one common posture; i.e., a "majority" posture. The test takes the form of H_0: $p \leq 0.5$ and H_A: $p > 0.5$. The random variable X_i (i = 1 to 81, for sample of 81 expert subjects) takes on the value 1 when a subject picks the posture with largest number of responses (i.e., the "favored" posture) in the cell under consideration; the probability that $X_i = 1$ is p. The random variable X_i takes on the value 0 if the subject picks any other posture; the

probability that $X_j = 0$ is $(1 - p)$. If there is a tie for the favored posture, the test cannot logically result in a rejection of the null hypothesis. Assuming there is a favored posture, a test must be constructed to decide whether to (1) reject the null hypothesis or (2) not reject the null hypothesis because of insufficient evidence to the contrary. The appropriate distribution is the distribution of the sum of the random variables X_j. This is the binomial distribution with parameters $N = 81$ and $p = 0.5$. A critical region must then be determined for which the null hypothesis is rejected when in fact true with no more than a stated probability. This probability is referred to as alpha, the significance level of the test. Typically a value of alpha = 0.05 is taken; for the case under consideration, the critical region corresponds to a count of responses of $K = 48$. For alpha = 0.01, $K = 52$. On this basis, the count for each of the 27 cells is tested in the hope of rejecting the null hypothesis. Table 6-2 displays the results of the test. The favored posture is designated in the cell for the given levels of the factors C, M, and N. The number of subjects of the total of 81 choosing the posture is indicated in parentheses. Double asterisks ** indicate that the null hypothesis can be rejected at the alpha = 0.01 level of significance, and a single asterisk * indicates that the null hypothesis can be rejected at the alpha = 0.05 level. For the remaining cells (those without asterisks), there is insufficient evidence to reject the null hypothesis; indeed, as noted in the table, for some cells there is no favored posture.

Table 6-2. Decision 4 "Favored" Postures

Posture of parent army	Force ratio	Location of objective		
		Rear	Reached	Forward
Delay	1:3	Delay (51)*	Defend (42)	Defend (56)**
	1:1	Delay (47)	Defend (46)	Defend (51)*
	3:1	Delay (31)#	Defend (39)#	Attack (58)**
Defend	1:3	Defend (37)#	Defend (72)**	Defend (68)**
	1:1	Defend (47)	Defend (70)**	Defend (52)**
	3:1	Defend (38)#	Defend (53)**	Attack (70)**
Attack	1:3	Defend (59)**	Defend (61)**	Defend (51)*
	1:1	Defend (53)**	Defend (49)*	Attack (43)
	3:1	Attack (52)**	Attack (67)**	Attack (81)**

Key:

*: significant at alpha = 0.05
**: significant at alpha = 0.01
#: no majority posture

Note that the following set of rules can be inferred from the data:

If army posture is delay, then corps posture is --

Delay when objective is to rear,
Attack when objective is forward and force ratio is at least 3:1, and
Defend in all other cases.

If army posture is defend, then corps posture is --

Attack when objective is forward and force ratio is at least 3:1, and
Defend in all other cases.

If army posture is attack, then corps posture is --

Attack when force ratio is at least 3:1,
Attack when objective is forward and force ratio is at least 1:1, and
Defend in all other cases.

From the structure of the test and the responses of the subjects, certain other patterns emerge.

a. The response "withdraw" is not selected as the largest response for any of the 27 cells. It can be assumed by the structure of the responses that "withdraw" could only apply with a friendly-to-enemy force ratio of less than 1:3.

b. When the posture of the parent army is attack, only one cell at the level of factors chosen is indeterminant (i.e., force ratio = 1:1, location = forward). This seems to indicate an unidentified defend/attack threshold somewhere between this cell and the cell for force ratio = 1:3, location = forward.

c. When the posture of the parent army is defend or delay, and the location of the objective is forward, an attack/defend threshold appears to lie between force ratios of 1:1 and 3:1.

d. When the posture of the parent army is defend and the location of the objective is to the rear, the majority posture may be difficult to establish. The largest number of responses are defend. For force ratio 1:3 and 1:1, delay is a close alternative with 32 and 25 responses, respectively. At force ratio 3:1, there is a tossup for second alternative between delay and attack with 17 responses each.

e. When the posture of the parent army is delay and the location of the objective is reached, or both the location is rear and the force ratio is at least 1:1, then the majority posture may be difficult to establish.

CHAPTER 7

FINDINGS AND RECOMMENDATIONS

7-1. FINDINGS

a. The most important product of this study is the methodology--"off-line" experiments with subjects acting as decisionmakers, followed by statistical analysis. This methodology can be used to develop rules initially or to modify existing rules.

b. Based on the experiments, it can be concluded that for each decision listed in Table 1-1, Chapter 1, all of the perception data base variables used in the rules currently in FORCEM are significant; i.e., relevant to the decision. This conclusion must be caveated, however, since only those variables are referenced in the experiments. Were additional, relevant variables to be introduced, it is conceivable that some of the variables in the current rules would become less significant.

c. For decisions 1, 5, 6, 7, and 8, the cell means shown in Tables I-4, I-16, I-20, I-24, and I-28 of Appendix I adequately represent the choices of the subjects; so also do the prediction equations displayed in Figure 6-1 and Table 6-1. For decisions 2 and 3, the cell means shown in Tables I-8 and I-12 of Appendix I adequately represent subjects' choices. For decision 4, the "favored" postures of Table 6-2 show subjects' preferences.

d. Regarding the validity of the rules currently in FORCEM, for decisions 1, 2, and 3, the ranking by need generated by the cell means differs clearly from the ranking generated by the current rules. This indicates that the rules could be replaced with table lookup procedures based on the cell means in order to obtain "better" decisions. However, the limited experience of the subjects in decisionmaking at the echelons considered in the experiments, and the lack of knowledge of the subjects about FORCEM itself, argue for great caution in accepting the cell means data as gospel and applying such data in FORCEM. In summary, the experiments for decisions 1, 2, and 3 do not validate the rules currently in FORCEM; but the experiments do not invalidate the rules either. Regarding decisions 4 through 8, the decisions in FORCEM are already made using table lookup procedures; the experiments yield no additional information on the validity of these decisions.

e. As suggested by subjects in written comments on the post-experiment questionnaires, and by Red experts in discussions, there are shortcomings to the representation of C^2 in FORCEM. Brief titles indicating the general areas of the shortcomings are shown in Figure 7-1. More detailed descriptions are given in Appendix J.

- Contingent change in posture
- Holding arriving division
- Echelon at which decision made
- Artillery support
- AirLand battle
- Personnel issues
- Time in combat and rate of loss
- Breakthrough
- Weather
- Overall consideration of time
- Combat reserves
- OPORDER methodology

Figure 7-1. Shortcomings in FORCEM C^2

f. In their written comments on the post-experiment questionnaires, subjects suggest several variables for use as decision criteria that are not currently in the FORCEM perception data base. These are listed in Figure 7-2. Appendix K describes these variables more fully and indicates how they might be computed within FORCEM.

- Rate of loss for friendly forces
- Rate of loss for enemy forces
- Time in sustained combat for friendly forces
- Time in sustained combat for enemy forces
- Geographical momentum
- Projected rate of movement
- Number of divisions that can be placed in area
- Status of artillery support
- Status of CAS
- Control of air
- Enemy posture

Figure 7-2. Additional Perception Data Base Variables

g. In their written comments on the post-experiment questionnaires, subjects suggest the use of additional decision criteria in making specific decisions. Figure 7-3 displays these suggestions, with the format of the decision followed by a list of existing perception data base variables to be used as decision criteria for that decision over and above the perception data base variables used in the rules currently in FORCEM. Appendix L explains these suggestions in greater detail.

- Assignment of new field artillery battalion
  - Posture of potential receiving corps
  - Status of divisional field artillery
- Designation of posture of online corps
  - Terrain
  - Status of associated corps support complex
  - Information on neighboring online corps
- Priority to corps (or division) for CAS
  - Posture of corps (or division)
  - Adequacy of recent CAS support
- Priority to corps (or division) for CAS
  - Posture of corps (or division)
  - Current CSS status of associated corps support complex (or of division and associated division support complex)

Figure 7-3. Expanded Criteria for Decisions

7-2. RECOMMENDATIONS

a. For testing purposes, table lookup procedures should be installed in FORCEM for decisions 1, 2, and 3. Then testing should be conducted to assess the reasonableness of the outcomes of the decisions when the data from this study are used; namely, the cell means data in Tables I-4, I-8, I-12, I-16, I-20, I-24, and I-28 of Appendix I, and the favored posture data in Table 6-2 of Chapter 6. In preparing the input data for decisions 5 through 8, each entry in the cell means tables (Tables I-16, I-20, I-24, and I-28) must be converted judgmentally from the qualitative ranking scale 0 to 100 to the quantitative apportioning scale ∞ to 1, as discussed in paragraph 6-2f(4), Chapter 6.

b. Add the variables in Figure 7-2 to the FORCEM perception data base.

c. Perform in-house experiments for the decisions shown in Figure 7-3 in order to determine how to best utilize the suggested expanded set of decision criteria.

d. The primary focus of this study--decision rules in FORCEM--and the approach taken considering the rules--offline experiments based on the decisions--yield little information regarding the use of FORGE. Nevertheless, the techniques for gathering data for this study can be adapted to yield methods for recording FORGE gamers' decisions. The following two suggestions are offered:

(1) For the near term, prepare a brief questionnaire for use with each of the 16 FORGE decisions. The questionnaire would be completed by a gamer at the completion of interactive activities during an interrupt wherein the gamer made a decision of that form. It would solicit the data items used in making the decisions, with the items grouped into the categories shown in paragraphs 7-2d(1)(a) through 7-2d(1)(d) below. Furthermore, the gamer would be asked to rank the items by importance.

(a) Perception data base variables used in the rules currently in FORCEM. These would be listed explicitly, with a simple "yes" or "no" sought.

(b) Perception data base variables suggested in Figure 7-3, should the decision be one of the four listed there. Again, the variables would be listed explicitly, with a simple "yes" or "no" sought.

(c) Graphics display, with an associated request for written explanation for what graphics information was used.

(d) Other data, with a request for a written list of such data items.

(2) For the longer term, develop software to solicit the necessary data items from the gamer in an interactive manner. At the completion of interactive gamer entries, save gamer decisions, then when FORCEM is reactivated keep the gamer workstation active and present the questionnaires discussed above to the gamer on the menu screen for completion interactively.

e. Whether and how to use FORGE to validate and enhance the decision rules in FORCEM should be topics for future study.

f. Based on review of the results of the experiments and on the written comments by the subjects, the following suggestions are offered for approaches to be taken should studies similar to this one be contemplated:

(1) Availability of Knowledgeable Person. When US Army officers are asked to provide answers to questions related to computer models, information on the model and the associated concepts should be available to the subjects. This was done for this study by providing a background information paper for each of the experiments. Based on the subsequent written comments of the subjects, this approach was insufficient. It would be well to ensure that when such an experiment is administered, a person who knows the model in depth is present to answer questions.

(2) Use of Familiar Terminology. Certain concepts used in computer models are adaptations of concepts more familiar to US Army officers; the intended meanings of the model concepts can be lost in an experiment referencing them. For example, in this study, the subjects objected to the use of the terms "echelon," "posture," and "army objective phase line." Providing background material describing the intended meaning of model concepts is one approach to preventing potential confusion. Another method is to make every effort to use terminology familiar to the subjects when describing the concepts. The latter approach is appropriate in a larger context whenever briefings on the model are given.

(3) Benchmark Values. When an experiment is administered wherein the subject is asked to provide a "grade" or "rank" to each of a number of situations generated by varying one or more decision variables, the full ranges of the decision variables should be described; or a "benchmark" example should be given to the subject before the experiment (i.e., a sample with a suggested grade). This prevents the grade assigned by the subject for an early situation from precluding consistent assignment of grades for subsequent situations (possibly more extreme than the early one).

APPENDIX A

STUDY CONTRIBUTORS

1. STUDY TEAM

a. Study Director

Dr. James J. Metzger

b. Team Members

Mr. Carl F. Bates
Mr. Franklin E. Womack
Mr. Ronald B. Bonniwell
Mr. Thomas C. Johnson

2. PRODUCT REVIEW BOARD

a. Chairperson

Mr. Ronald J. Iekel

b. Members

MAJ Berner R. Johnson, Jr.
Mr. James S. Tesauro (Co-Op)
MAJ Glen R. White

3. EXTERNAL CONTRIBUTORS

a. Dr. Sam Parry, a professor at the Naval Postgraduate School. As a visiting analyst at the US Army Concepts Analysis Agency, Dr. Parry developed the concept for combining expert judgment and statistical analysis as a means of enhancing the representation of command and control in FORCEM, and thereby provided the basic structure for the study.

b. CPT Douglas Fletcher, a student at the Naval Postgraduate School. During an experience tour at CAA, he implemented in FORCEM and tested the prediction equation resulting from the pretest on Decision 1, Assign New Corps.

c. Mr. Dennis Leedom, Assistant Director, Systems Research Laboratory, US Army Research Institute for the Behavioral and Social Sciences, developed the questionnaire shown in Appendix D and compiled the summary of responses shown in Appendix F.

APPENDIX B

STUDY DIRECTIVE

CSCA-ASD

15 AUG 1985

MEMORANDUM FOR ASSISTANT DIRECTOR, AS

SUBJECT: C^2 Enhancements for FORCEM (CENFOR) Study

1. PURPOSE. This directive provides tasking for a study to develop and apply methodologies for validating and enhancing the command and control (C^2) decision rules in the Force Evaluation Model (FORCEM).

2. BACKGROUND

a. FORCEM is a fully-automated computer model treating combat, combat support, and combat service support in a theater. C^2 is represented through a specified set of decisions treated in a predetermined order. Each decision involves the application of embedded rules based on preselected information from the perceived data base. The only control available to the user is the designation of threshold values to which data from the perceived data base are compared.

b. The FORCEM Gaming Evaluator Model (FORGE) is an interactive version of FORCEM being developed under contract to allow gamers to direct the overall pattern of a particular situation by making many of the key decisions. Those decisions constitute a subset of the decisions made in an automated manner by FORCEM. In making each decision, a gamer is to have available the information in the perceived data base (not just the data used in the rules embedded in FORCEM) plus graphics displays.

c. The objectives of FORGE are as follows:

(1) To validate and enhance the current decision rules in FORCEM.

(2) To provide an alternative to the McClintic Theater Model/Joint Theater Level Simulation for evaluation of large scale operations plans.

(3) To provide a training model for users such as the Army War College and the Naval Postgraduate School.

(4) To generate scenarios for users such as the Warrior Preparation Center.

d. FORGE provides a valuable tool to evaluate the automated representation of C^2 in FORCEM.

3. STUDY SPONSOR. US Army Concepts Analysis Agency (CAA).

4. STUDY AGENCY. Models Development Division, Analysis Support Directorate (AS), CAA.

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SUBJECT: C^2 Enhancements for FORCEM (CENFOR) Study

5. TERMS OF REFERENCE.

a. Scope. This study is limited to developing and applying methods for validating and enhancing the decision rules in FORCEM, using FORGE as an experimental environment.

b. Objectives.

(1) To develop and apply methodologies to --

(a) Examine specific decisions using scenarios extracted from FORCEM or FORGE, including selected data from the perceived data base and graphics displays,

(b) Prepare and exercise "offline" experiments based on the scenarios, and

(c) Apply the information collected from the experiments to validate and enhance the decision rules in FORCEM, and to design methodologies for use during the actual exercise of FORGE.

(2) To develop methodologies to --

(a) Record gamer decision processes during the exercise of FORGE, and

(b) Use the information collected from gamers to validate and enhance the decision rules in FORCEM.

(3) Make recommendations for actual exercises of FORGE using the methodologies of 5b(2) above.

c. Assumption: FORCEM provides an adequate context for examining C^2 issues at echelons above division.

d. Essential Elements of Analysis

(1) Are the decisions currently represented in FORCEM appropriate for a theater-level model?

(2) For each decision, what are the critical data; i.e., what are the pertinent data items from the perceived data base?

(3) Are the decision rules embedded in FORCEM appropriate? If not, how should they be expanded or modified?

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SUBJECT: C^2 Enhancements for FORCEM (CENFOR) Study

6. RESPONSIBILITIES

a. Analysis Support Directorate (AS) has primary responsibility for accomplishment of the objectives listed in paragraph 5b. It will provide the study director. It will extract scenarios from FORCEM for use in offline experiments. It will direct offline experiments using scenarios derived from FORCEM or FORGE.

b. All CAA directorates will provide officers to serve as players in offline experiments. Strategy, Concepts, and Plans Directorate (SP) will also provide technical advice and assistance in extracting scenarios from FORGE for use in offline experiments.

c. Management and Support Directorate (MS) will provide the CAA Red Team to validate methodology and rules concerning Red decisions.

d. The US Army Research Institute for the Behavioral and Social Sciences (ARI) will provide consulting assistance in selecting information from FORCEM or FORGE for use in offline experiments, and in designing methods for recording gamer decision processes during the actual exercise of FORGE.

7. LITERATURE SEARCH. The following documents will be utilized in the study.

a. "Command and Control in the Force Evaluation Model," CAA Technical Paper CAA-TP-84-8, Jun 84.

b. "Command and Control in the Force Evaluation Model," Internal CAA Document, Feb 85.

c. "Interactive Theatre Wargame (FORGE), Program Specification (PS)," Harris Corporation, Apr 85.

8. REFERENCES

a. AR 5-5, Army Studies and Analyses, Nov 81.

b. DA PAM 5-5, Guidance for Army Study Sponsors, Sponsor's Study Directors, Study Advisory Groups, and Contracting Officer Representatives, Apr 82.

9. ADMINISTRATION

a. Milestone Schedule. See CAA Form 59 (Enclosure 1).

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b. Reporting. Models Development Division, AS, will submit DD Forms 1498 and 1473 to the Defense Technical Information Center, in accordance with AR 5-5 and DA PAM 5-5.

c. Documentation. The methodology developed, conclusions drawn, and recommendations made, will be documented in a final report.

E. B. Vandiver III

Encl

E. B. VANDIVER III
Director

CF:
Asst Dir, FO
Asst Dir, FS
Asst Dir, MS
Asst Dir, RQ
Asst Dir, SP

APPENDIX C

INFORMATION PAPERS

This appendix contains copies of the information papers provided to CENFOR subjects prior to the experiments. Corresponding to each experiment is an information paper that describes FORCEM, the decision being made, and the variables from the perception data base that are used in the rules currently in FORCEM and are to be controlled and varied in the experiment.

ASSIGN NEW CORPS

A. GENERAL.

The Force Evaluation Model (FORCEM) is a computer simulation developed by the US Army Concepts Analysis Agency. It treats combat, combat support, and combat service support (CSS) in a theater of operations. Activities are represented at four echelons: theater, army, corps, and division (in US terminology). The primary unit for combat is the division. The representation of command and control (C2) is fully-automated. For each theater, army, and corps headquarters (HQS), decisions are made internally by FORCEM about, or that directly affect, immediate subordinates. Thus, for example, an army HQS assigns a priority for CSS to each of its subordinate corps'. For each decision for a HQS, there is a set of rules encoded into FORCEM that, in turn, reference a predetermined set of parameters from the "perception database" (containing perceived information about the HQS itself, its subordinates, and enemy forces), and that apply, as well, input threshold parameters.

The purpose of this experiment, and of the subsequent statistical analysis to be performed on the results, is to validate, an possibly enhance, the representation of one such decision by determining--

1. whether the parameters currently used from the perception database are necessary and proper, and if so, how they should be combined in making the decision.

2. whether additional information is relevant, and should be added to the list of parameters used in the decision.

The experiment itself will be administered on the VAX minicomputer. After the experiment, a questionnaire will be provided to be completed in handwritten form; it will also assist in achieving the above goal.

B. SPECIFIC.

The topic of this experiment is the decision on assignment of a newly arrived corps. Such a corps (with its subordinate divisions) may enter the theater after the beginning of the simulation. If the corps is not preassigned by the user to an existing army, and further to reserve status behind an existing online corps, then logic internal to FORCEM does so. (Another decision in FORCEM, not considered in this experiment, involves subsequent commitment to combat of the reserve corps.)

The mechanism used in determining the online corps behind which the newly arrived corps is to be assigned in reserve involves ranking the potential receiving online corps' by need, and then selecting the online corps with the greatest need. The need of an online corps is specified by a numerical criticality that is computed based on the perception database parameters shown below. These are the parameters to be varied in the experiment.

1. whether the online corps currently has no reserve corps behind it, or currently has one or more reserve corps' behind it. (For the experiment, read "one corps in reserve" to mean "one or more corps' is reserve".)

2. whether or not the online corps is engaged.

ASSIGN NEW CORPS

3. The location of the parent army's objective phase line relative to the location of the online corps. The army objective phase line designates the desired locations to be reached (or held) by subordinate online corps within the army, and is input to FORCEM by the user. (The term "forward control phase line of a corps" is also used; this is an internal model artifice for controlling the movement of subordinate divisions. For the purposes of this experiment, read "forward control phase line of a corps" to mean "location of the corps" to mean "location of the most forward division in the corps".) The army objective phase line can be "forward" of the location of the online corps, "at" the location of the online corps, or "to the rear" of the location of the online corps.

4. The posture of the online corps (i.e., attack, defend, delay, or withdraw). The posture is the mission assigned to the online corps by its parent army HQS.

5. The friendly-to-enemy force ratio faced by the online corps, as perceived by the parent army HQS.

ASSIGN NEW DIVISION

A. GENERAL.

The Force Evaluation Model (FORCEM) is a computer simulation developed by the US Army Concepts Analysis Agency. It treats combat, combat support, and combat service support (CSS) in a theater of operations. Activities are represented at four echelons: theater, army, corps, and division (in US terminology). The primary unit for combat is the division. The representation of command and control (C2) is fully-automated. For each theater, army, and corps headquarters (HQS), decisions are made internally by FORCEM about, or that directly affect, immediate subordinates. Thus, for example, an army HQS assigns a priority for CSS to each of its subordinate corps'. For each decision for a HQS, there is a set of rules encoded into FORCEM that, in turn, reference a predetermined set of parameters from the "perception database" (containing perceived information about the HQS itself, its subordinates, and enemy forces), and that apply, as well, input threshold parameters.

The purpose of this experiment, and of the subsequent statistical analysis to be performed on the results, is to validate, an possibly enhance, the representation of one such decision by determining--

1. whether the parameters currently used from the perception database are necessary and proper, and if so, how they should be combined in making the decision.

2. whether additional information is relevant, and should be added to the list of parameters used in the decision.

The experiment itself will be administered on the VAX minicomputer. After the experiment, a questionnaire will be provided to be completed in handwritten form; it will also assist in achieving the above goal.

B. SPECIFIC.

The topic of this experiment is the decision on assignment of a newly arrived division. Such a division may enter the theater after the beginning of the simulation. If the division is not preassigned by the user to an existing (or newly arriving) corps, then logic internal to FORCEM does so.

The mechanism used in determining the corps to which the newly arrived division is to be assigned involves ranking the potential receiving corps' by need, and then selecting the corps with the greatest need. The need of a corps is specified by a numerical criticality that is computed based on the perception database parameters shown below. These are the parameters to be varied in the experiment.

1. whether the existing corps is online or reserve.

2. If online, the number of reserve corps' behind it; if reserve, echelon to which it is assigned.

3. whether or not the corps is engaged.

4. The location of the parent army's objective phase line relative to the location of the corps. The army objective phase line designates the desired locations to be reached (or held) by subordinate online corps' within the

army, and is input to FORCE* by the user. (The term "forward control phase line of a corps" is also used; this is an internal model artifice for controlling the movement of subordinate divisions. For the purposes of this experiment, read "forward control phase line of a corps" to mean "location of the corps" to mean "location of the most forward division in the corps".) The army objective phase line can be "forward" of the location of the corps, "at" the location of the corps, or "to the rear" of the location of the corps.

5. The posture of the corps (i.e., attack, defend, delay, or withdraw). The posture is the mission assigned to the corps by its parent army HQS.

6. The friendly-to-enemy force ratio faced by the corps, as perceived by the parent army HQS.

ASSIGN NEW ARTILLERY BATTALION

A. GENERAL.

The Force Evaluation Model (FORCEM) is a computer simulation developed by the US Army Concepts Analysis Agency. It treats combat, combat support, and combat service support (CSS) in a theater of operations. Activities are represented at four echelons: theater, army, corps, and division (in US terminology). The primary unit for combat is the division. The representation of command and control (C2) is fully-automated. For each theater, army, and corps headquarters (HQS), decisions are made internally by FORCEM about, or that directly affect, immediate subordinates. Thus, for example, an army HQS assigns a priority for CSS to each of its subordinate corps. For each decision for a HQS, there is a set of rules encoded into FORCEM that, in turn, reference a predetermined set of parameters from the "perception database" (containing perceived information about the HQS itself, its subordinates, and enemy forces), and that apply, as well, input threshold parameters.

The purpose of this experiment, and of the subsequent statistical analysis to be performed on the results, is to validate, an possibly enhance, the representation of one such decision by determining--

1. whether the parameters currently used from the perception database are necessary and proper, and if so, how they should be combined in making the decision.

2. whether additional information is relevant, and should be added to the list of parameters used in the decision.

The experiment itself will be administered on the VAX minicomputer. After the experiment, a questionnaire will be provided to be completed in handwritten form; it will also assist in achieving the above goal.

B. SPECIFIC.

The topic of this experiment is the decision on assignment of a newly arrived field artillery battalion. Such a unit may enter the theater after the beginning of the simulation. If the unit is not preassigned by the user to an existing HQS, then logic internal to FORCEM assigns the unit to an existing corps HQS.

The mechanism used in determining the corps HQS to which the newly arrived field artillery battalion is to be assigned involves ranking the potential receiving corps by need, and then selecting the corps with the greatest need. The need of a corps is specified by a numerical criticality that is computed based on the perception database parameters shown below. These are the parameters to be varied in the experiment.

1. whether the corps is online or reserve.

2. The ratio of the number of corps-level field artillery battalions currently assigned to the corps HQS, to the number of divisions in the corps. For example, a ratio of 0.25 means that there is one corps-level field artillery battalion for each four divisions.

3. The location of the parent army's objective phase line relative to the location of the corps. The army

objective phase line designates the desired locations to be reached (or held) by subordinate online corps within the army, and is input to FORCEM by the user. (The term "forward control phase line of a corps" is also used; this is an internal model artifice for controlling the movement of subordinate divisions. For the purposes of this experiment, read "forward control phase line of a corps" to mean "location of the corps" to mean "location of the most forward division in the corps".) The army objective phase line can be "forward" of the location of the corps, "at" the location of the corps, or "to the rear" of the location of the corps.

4. The posture of the corps (i.e., attack, defend, delay, or withdraw). The posture is the mission assigned to the corps by its parent army HQS.

5. Whether or not the corps is engaged.

DESIGNATE POSTURE OF ONLINE CORPS

A. GENERAL.

The Force Evaluation Model (FORCEM) is a computer simulation developed by the US Army Concepts Analysis Agency. It treats combat, combat support, and combat service support (CSS) in a theater of operations. Activities are represented at four echelons: theater, army, corps, and division (in US terminology). The primary unit for combat is the division. The representation of command and control (C2) is fully-automated. For each theater, army, and corps headquarters (HQS), decisions are made internally by FORCEM about, or that directly affect, immediate subordinates. Thus, for example, an army HQS assigns a priority for CSS to each of its subordinate corps'. For each decision for a HQS, there is a set of rules encoded into FORCEM that, in turn, reference a predetermined set of parameters from the "perception database" (containing perceived information about the HQS itself, its subordinates, and enemy forces), and that apply, as well, input threshold parameters.

The purpose of this experiment, and of the subsequent statistical analysis to be performed on the results, is to validate, an possibly enhance, the representation of one such decision by determining--

1. Whether the parameters currently used from the perception database are necessary and proper, and if so, how they should be combined in making the decision.

2. Whether additional information is relevant, and should be added to the list of parameters used in the decision.

The experiment itself will be administered on the VAX minicomputer. After the experiment, a questionnaire will be provided to be completed in handwritten form; it will also assist in achieving the above goal.

B. SPECIFIC.

The topic of this experiment is the decision by an army HQS on the posture of a subordinate online corps. By posture is meant the assigned mission; within FORCEM, posture has one of four values: attack, defend, delay, or withdraw. Conceptually, the posture of an online corps designates the intensity with which the corps is to attempt to move forward toward (or hold at) the army's objective phase line. The latter is described below.

The decision on the posture of an online corps is based on the perception database parameters shown below. These are the parameters to be varied in the experiment.

1. The friendly-to-enemy force ratio faced by the online corps, as perceived by the army HQS.

2. The location of the army's objective phase line relative to the location of the corps; i.e., the army objective phase line is "forward" of the corps, "at the location" of the corps, or "to the rear" of the corps. The army objective phase line designates the desired locations to be reached (or held) by subordinate online corps' within the army.

3. The posture of the army HQS (again, attack, defend, delay, or withdraw) as specified by the model user.

SPECIFY PRIORITY TO CORPS FOR CAS

A. GENERAL.

The Force Evaluation Model (FORCEM) is a computer simulation developed by the US Army Concepts Analysis Agency. It treats combat, combat support, and combat service support (CSS) in a theater of operations. Activities are represented at four echelons: theater, army, corps, and division (in US terminology). The primary unit for combat is the division. The representation of command and control (C2) is fully-automated. For each theater, army, and corps headquarters (HQS), decisions are made internally by FORCEM about, or that directly affect, immediate subordinates. Thus, for example, an army HQS assigns a priority for CSS to each of its subordinate corps'. For each decision for a HQS, there is a set of rules encoded into FORCEM that, in turn, reference a predetermined set of parameters from the "perception database" (containing perceived information about the HQS itself, its subordinates, and enemy forces), and that apply, as well, input threshold parameters.

The purpose of this experiment, and of the subsequent statistical analysis to be performed on the results, is to validate, an possibly enhance, the representation of one such decision by determining--

1. whether the parameters currently used from the perception database are necessary and proper, and if so, how they should be combined in making the decision.

2. whether additional information is relevant, and should be added to the list of parameters used in the decision.

The experiment itself will be administered on the VAX minicomputer. After the experiment, a questionnaire will be provided to be completed in handwritten form; it will also assist in achieving the above goal.

B. SPECIFIC.

The topic of this experiment is the decision by an army HQS on the priority of a subordinate corps for close air support (CAS). This priority is a numerical value that is use in the FORCEM fire support module in the distribution of CAS aircraft sorties by the army HQS to subordinate corps when requirements for CAS exceed available aircraft.

The decision on the CAS priority of a corps is based on the perception database parameters shown below. These are the parameters to be varied in the experiment.

1. echelon to which the corps is assigned (online or reserve).

2. whether or not the corps is engaged.

3. The friendly-to-enemy force ratio faced by the corps, as perceived by the army HQS.

The experiment uses the term "criticality" for CAS support. Read "criticality" to mean "priority".

SPECIFY PRIORITY TO CORPS FOR CSS

A. GENERAL.

The Force Evaluation Model (FORCE™) is a computer simulation developed by the US Army Concepts Analysis Agency. It treats combat, combat support, and combat service support (CSS) in a theater of operations. Activities are represented at four echelons: theater, army, corps, and division (in US terminology). The primary unit for combat is the division. The representation of command and control (C2) is fully-automated. For each theater, army, and corps headquarters (HQS), decisions are made internally by FORCE™ about, or that directly affect, immediate subordinates. Thus, for example, an army HQS assigns a priority for CSS to each of its subordinate corps'. For each decision for a HQS, there is a set of rules encoded into FORCE™ that, in turn, reference a predetermined set of parameters from the "perception database" (containing perceived information about the HQS itself, its subordinates, and enemy forces), and that apply, as well, input threshold parameters.

The purpose of this experiment, and of the subsequent statistical analysis to be performed on the results, is to validate, an possibly enhance, the representation of one such decision by determining--

1. whether the parameters currently used from the perception database are necessary and proper, and if so, how they should be combined in making the decision.

2. whether additional information is relevant, and should be added to the list of parameters used in the decision.

The experiment itself will be administered on the VAx minicomputer. After the experiment, a questionnaire will be provided to be completed in handwritten form; it will also assist in achieving the above goal.

B. SPECIFIC.

The topic of this experiment is the decision by an army HQS on the priority of a subordinate corps for CSS support. This priority is a numerical value that is used in the FORCE™ CSS module in the distribution of supplies and replacement personnel and vehicles when demand exceeds available resources.

The decision on the CSS priority of a corps is based on the perception database parameters shown below. These are the parameters to be varied in the experiment.

1. Echelon to which the corps is assigned (online or reserve).

2. whether or not the corps is engaged.

3. The friendly-to-enemy force ratio faced by the corps, as perceived by the army HQS.

The experiment uses the term "criticality" for CAS support. Read "criticality" to mean "priority".

SPECIFY PRIORITY TO DIVISION FOR CAS

A. GENERAL.

The Force Evaluation Model (FORCEM) is a computer simulation developed by the US Army Concepts Analysis Agency. It treats combat, combat support, and combat service support (CSS) in a theater of operations. Activities are represented at four echelons: theater, army, corps, and division (in US terminology). The primary unit for combat is the division. The representation of command and control (C2) is fully-automated. For each theater, army, and corps headquarters (HQS), decisions are made internally by FORCEM about, or that directly affect, immediate subordinates. Thus, for example, an army HQS assigns a priority for CSS to each of its subordinate corps'. For each decision for a HQS, there is a set of rules encoded into FORCEM that, in turn, reference a predetermined set of parameters from the "perception database" (containing perceived information about the HQS itself, its subordinates, and enemy forces), and that apply, as well, input threshold parameters.

The purpose of this experiment, and of the subsequent statistical analysis to be performed on the results, is to validate, an possibly enhance, the representation of one such decision by determining--

1. Whether the parameters currently used from the perception database are necessary and proper, and if so, how they should be combined in making the decision.

2. Whether additional information is relevant, and should be added to the list of parameters used in the decision.

The experiment itself will be administered on the VAX minicomputer. After the experiment, a questionnaire will be provided to be completed in handwritten form; it will also assist in achieving the above goal.

B. SPECIFIC.

The topic of this experiment is the decision by a corps HQS on the priority of a subordinate division for close air support (CAS). This priority is a numerical value that is use in the FORCEM fire support module in the distribution of CAS aircraft sorties by the corps to subordinate divisions when requirements for CAS exceed available aircraft.

The decision on the CAS priority of a division is based on the perception database parameters shown below. These are the parameters to be varied in the experiment.

1. Echelon to which the division is assigned (i.e., first echelon = committed to combat; second echelon = available for combat but not committed; or third echelon = in repair and refurbishment).

2. Whether or not the division is engaged.

3. The friendly-to-enemy force ratio faced by the division, as perceived by the corps HQS.

The experiment uses the term "criticality" for CAS support. Read "criticality" to mean "priority".

SPECIFY PRIORITY TO DIVISION FOR CSS

A. GENERAL.

The Force Evaluation Model (FORCEM) is a computer simulation developed by the US Army Concepts Analysis Agency. It treats combat, combat support, and combat service support (CSS) in a theater of operations. Activities are represented at four echelons: theater, army, corps, and division (in US terminology). The primary unit for combat is the division. The representation of command and control (C2) is fully-automated. For each theater, army, and corps headquarters (HQS), decisions are made internally by FORCEM about, or that directly affect, immediate subordinates. Thus, for example, an army HQS assigns a priority for CSS to each of its subordinate corps'. For each decision for a HQS, there is a set of rules encoded into FORCEM that, in turn, reference a predetermined set of parameters from the "perception database" (containing perceived information about the HQS itself, its subordinates, and enemy forces), and that apply, as well, input threshold parameters.

The purpose of this experiment, and of the subsequent statistical analysis to be performed on the results, is to validate, an possibly enhance, the representation of one such decision by determining--

1. whether the parameters currently used from the perception database are necessary and proper, and if so, how they should be combined in making the decision.

2. whether additional information is relevant, and should be added to the list of parameters used in the decision.

The experiment itself will be administered on the VAX minicomputer. After the experiment, a questionnaire will be provided to be completed in handwritten form; it will also assist in achieving the above goal.

B. SPECIFIC.

The topic of this experiment is the decision by a corps HQS on the priority of a subordinate division for CSS support. This priority is a numerical value that is used in the FORCEM CSS module in the distribution of supplies and replacement personnel and vehicles when demand exceeds available resources.

The decision on the CSS priority of a division is based on the perception database parameters shown below. These are the parameters to be varied in the experiment.

1. echelon to which the division is assigned (i.e., first echelon = committed to combat; second echelon = available for combat but not committed; or third echelon = in repair and refurbishment).

2. whether or not the division is engaged.

3. the friendly-to-enemy force ratio faced by the division, as perceived by the corps HQS.

The experiment uses the term "criticality" for CSS support. Read "criticality" to mean "priority".

APPENDIX D

POST-EXPERIMENT QUESTIONNAIRE

This appendix contains a copy of the questionnaire prepared by the US Army Research Institute for the Behavioral and Social Sciences (ARI) for administration to subjects after completion of the experiments.

GENERAL INSTRUCTIONS

As a participant in this data collection exercise by the U.S. Army Concepts Analysis Agency, you are requested to provide some additional information which will assist us in better understanding how these types of battle management decisions are made under real combat conditions.

It is realized that the type of factors (variables) used in computer simulation models may or may not correspond to how commanders perceive a given combat situation, and may or may not correspond to the factors used in making certain types of battle management decisions. You will be asked to think about each of the factors provided to you and to assess their degree of importance, degree of realism, degree of uncertainty, and degree of scenario-dependence. You will be given the opportunity to list other factors which you consider to be important in making this battle management decision. Finally, you will be asked to recall how you made this decision and to describe images of typical scenarios which come to mind as you think about the various factors.

Please work through the questions in the order that they are presented. Provide as much detail or description as you wish in order to convey a particular idea, explanation, or reaction to a particular item. Please answer each question openly and freely —there are no right or wrong answers! Rather, we are attempting to discover how individuals such as yourself consciously work their way through specific types of battle management decisions.

Thank you for your cooperation!

Dennis K. Leedom
Systems Research Laboratory
U.S. Army Research Institute
for the Behavioral & Social Sciences

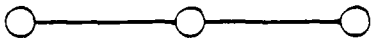
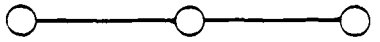
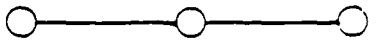
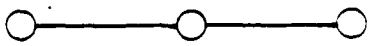
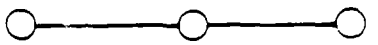
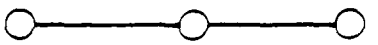
NAME _____

BATTLE MANAGEMENT DECISION [Circle number]

1. Assignment of new Corps
2. Assignment of new Division
3. Assignment of new artillery unit
4. Commitment of reserve Corps
5. Selection of Corps posture
6. Priority of Corps for Close Air Support
7. Priority of Corps for Combat Service Support
8. Priority of Division for Close Air Support
9. Priority of Division for Combat Service Support

DECISION FACTORS	DEGREE OF IMPORTANCE Low Moderate High
A. Number of Corps in *reserve* [0,1]	
B. Corps engagement status [No, Yes]	
C. Corps force ratio [1/3, 1/1, 3/1]	
D. Corps location and posture [Behind/Withdraw, ... In front/Attack]	
E. Corps status and number of Corps behind [Reserve, On-line/1 Res, On-line/0 Res]	
F. Echelon to which Corps is assigned [Reserve, On-line]	
G. Ratio of current artillery to current Divisions [1/1, 1/4]	
H. *Support status of reserve Corps* [Desparate, Poor, Okay]	
I. Number of combat ready Divisions in 1st, 2nd Ech [1,3]	
J. Have 2nd echelon Divisions been committed? [No, Yes]	
K. Is on-line Corps holding up advance of adj Corps? [No, Yes]	
L. Location of the Army Objective Phase Line [Behind, At, *In-front*]	
M. Current posture of Corps' parent Army [Delay, Defend, Attack]	
N. Division engagement status [No, Yes]	
O. Division combat worth force ratio [1/3, 1/1, 3/1]	
P. Echelon to which Division is assigned [3rd, 2nd, 1st]	

Are there any other factors (variables) that you consider influential in this specific battle management decision? If so, please briefly describe them and indicate their relative degree of importance:

DECISION FACTORS	DEGREE OF IMPORTANCE Low Moderate High
Q.	
R.	
S.	
T.	
U.	
V.	

DECISION FACTORS	DEGREE OF REALISM [Check one]	
	Artifact of simulation model	Real-world variable
A. Number of Corps in reserve	○———	———○
B. Corps engagement status	○———	———○
C. Corps force ratio	○———	———○
D. Corps location and posture	○———	———○
E. Corps status and number of Corps behind	○———	———○
F. Echelon to which Corps is assig ned	○———	———○
G. Ratio of current artillery to current Divisions	○———	———○
H. Support status of reserve Corps	○———	———○
I. Number of combat ready Divisions in 1st, 2nd Ech	○———	———○
J. Have 2nd echelon Divisions been committed?	○———	———○
K. Is on-line Corps holding up advance of adj Corps?	○———	———○
L. Location of Army Objective Phase Line	○———	———○
M. Current posture of Corps'parent Army	○———	———○
N. Division engagement status	○———	———○
O. Division combat worth force ratio	○———	———○
P. Echelon to which Division is assigned	○———	———○

For each factor considered to be an artifact of the simulation model, briefly describe how this information might be estimated from real-world data sources available to the commander:

DECISION FACTORS	DEGREE OF UNCERTAINTY [Check one]		
	Unknown	Moderate Uncertainty	Hard Data
A. Number of Corps in reserve			
B. Corps engagement status			
C. Corps force ratio			
D. Corps location and posture			
E. Corps status and number of Corps behind			
F. Echelon to which Corps is assigned			
G. Ratio of current artillery to current Divisions			
H. Support status of reserve Corps			
I. Number of combat ready Divisions in 1st, 2nd Ech			
J. Have 2nd echelon Divisions been committed?			
K. Is on-line Corps holding up advance of adj Corps?			
L. Location of Army Objective Phase Line			
M. Current posture of Corps' parent Army			
N. Division engagement status			
O. Division combat worth force ratio			
P. Echelon to which Division is assigned			

Briefly describe how you would take into account areas of uncertainty for this specific battle management decision. For example, would you operate in a more conservative manner, would you make a best-guess estimate of the factor, would you attempt to obtain more information, etc, etc.

DECISION FACTORS	SCENARIO DEPENDENCE [Check one]	
	This factor would influence my decision in a general sort of manner	The role/importance of this factor would be scenario-specific
A. Number of Corps in reserve	○	○
B. Corps engagement status	○	○
C. Corps force ratio	○	○
D. Corps location and posture	○	○
E. Corps status and number of Corps behind	○	○
F. Echelon to which Corps is assigned	○	○
G. Ratio of current artillery to current Divisions	○	○
H. Support status of reserve Corps	○	○
I. Number of combat ready Divisions in 1st, 2nd Ech	○	○
J. Have 2nd echelon Divisions been committed?	○	○
K. Is on-line Corps holding up advance of adj Corps?	○	○
L. Location of Army Objective Phase Line	○	○
M. Current posture of Corps' parent Army	○	○
N. Division engagement status	○	○
O. Division combat worth force ratio	○	○
P. Echelon to which Division is assigned	○	○

Briefly describe how the role/importance of specific factors might change as a function of scenario (eg, European, Korean, Southwest Asia, etc).

When you think about this specific battle management decision, does any particular prototypical situation come to mind? Is there any type of familiar scenario that is readily associated with this decision as you went through the exercise? Can you briefly describe it in terms of the actions, events, or conditions that would characterize such a scenario?

[Note: We are interested only in whether or not such prototypical scenarios come to mind when one is faced with this type of battle management decision —*there is no right or wrong answer!*]

Are there any other comments you would like to make?

APPENDIX E

WRITTEN RESPONSES TO QUESTIONNAIRES

This appendix contains a compilation of the written responses of subjects obtained from the questionnaire of Appendix D. The responses are categorized by question on the questionnaire. Within the responses for one category, the remarks by an individual subject are grouped together. The numbering of subjects for one category does not necessarily match the numbering for any other category; hence correlation of responses across questions is not possible here. The intent is to record responses and to give the reader the flavor of the types and numbers of responses by an individual subject.

ADDITIONAL DECISION FACTORS

Participant #1.

a. No. of casualties.

b. How goes the battle? Are we winning? Losing? Who has the forward momentum? We or they?

c. What is the status of other corps? Where are their weaknesses? On the flanks? To the center? Is there a breakthrough by the enemy? Where? What about battle terrain? Easily defended?

d. Consider weather! Where are the friendly (respectively, enemy) tanks? In the plain or in the hills?

e. Who commands enemy echelons above corps? How does he work? How good is his intelligence? How long has he been engaged? What are his losses?

Participant #2.

a. Availability of close air support (few sorties, some sorties, many sorties).

b. Availability of naval gunfire. Yes, No?

Participant #3.

a. Logistic capability to sustain the new battalion.

b. Current FA battalion status within division.

c. Future objectives.

d. Type enemy force (armored/mechanized/infantry).

Participant #4.

a. Amount of surveillance, reconnaissance systems up.

b. Success of national level intelligence support.

Participant #5.

a. Type divisions.

b. Degree of mobility.

Participant #6.

a. Combat power.

b. Terrain.

c. Mobility.

Participant #7.

a. Adjacent unit lines.

b. Percent of combat effectiveness.

c. Terrain and mobility.

d. Status of supply.

Participant #8.

a. Class V.

b. Class III.

c. Air situation.

Participant #9.

a. Mission of corps.

b. Degree of fire support in addition to close air support (CAS).

Participant #10.

a. Current and anticipated enemy threat (next 24 hrs).

b. Combat readiness/capability of the various corps.

c. Overall ammo, POL, and logistics status of the corps.

d. Morale, espirit de corps and fighting discipline of major subordinate units.

e. For CAS - the relative exigencies for other corps based on the threat to that/those corps.

f. For combat service support (CSS): relative army stockage/supply capabilities out of which to supply given corps.

Participant #11.

a. Who initiated engagement.

Participant #12.

a. Combat status of other units.

b. Force ratio status of other units.

c. Combat service support/combat support (CSS/CS) status of other units.

d. Artillery battalion to division ratio.

e. Status of enemy (attacking or defending).

Participant #13.

a. Corps strength (% effectiveness, morale, etc).

Participant #14.

a. Status of supply.

b. Mission.

Participant #15.

a. Who/which corps is "hurting" the worst?

b. What is the corps mission/objective?

Participant #16.

a. Status of flanking units.

b. Time in current battle.

c. Reserves.

d. Time enemy forces in current battle (fresh troop or tired troops).

e. Line of communication.

Participant #17.

a. Mission.

b. Combat support (CS).

c. Combat service support (CSS).

d. Scenario.

e. Log base.

Participant #18.

a. Day/night.

Participant #19.

a. Strength.

b. Morale/fitness.

c. Capability/equipment status.

Participant #20.

a. Status of units on flanks.

b. What is the enemy doing? (attacking, defending, etc.)

c. What echelon of enemy is engaged?

Participant #21.

a. Enemy air status.

b. Enemy follow-on echelon status.

c. Terrain.

d. Type divisions in corps.

e. Training status of division of corps.

f. Timing - time in relation to space.

Participant #22.

a. Relationship of flank friendly units (corps/division); i.e., location relative to my position.

b. Posture of flanking units.

c. Ammo and personnel status.

Participant #23.

a. Time of reaction to need; e.g., reserve corps.

Participant #24.

a. Force ratios of adjacent corps (online).

Participant #25.

a. Weather.

b. Aviation.

Participant #26.

a. Current level of combat service support (CSS) for corps.

b. Corps current mission.

Participant #27.

a. Doctrine.

Participant #28.

a. Type of terrain occupied (urban, forested, mountainous, flat, desert, etc.)?

b. Combat service support status (ammunition, fuel, combat (CBT) equipment systems status).

Participant #29.

a. Logistic posture.

b. Terrain.

c. Objective (campaign).

d. Weather.

e. Combat support.

Participant #30.

a. Capability to counterattack when defending.

b. Capability to overcome defenders counterattack when attacking.

c. Army's longer range operational plan.

d. Supply status of other corps.

e. Availability and timeliness of other army reserve assets.

Participant #31.

a. Overall status of army combat support good/close air support adequate.

Participant #32.

a. For combat service support (CSS), what is current fighting capability of division (100%, 90%, 75%, 50%)?

Participant #33.

a. Morale.

b. Weather.

c. Nuclear/chemical threat.

d. Terrain.

Participant #34.

a. Mission.

b. Commander's interest.

c. Situation of adjacent units.

Participant #35.

a. Length of time online or reserve.

b. Strength.

Participant #36.

a. Location, destination, and ETA for enemy's second echelon armies and corps.

b. Support status of online corps.

c. Control of the air.

Participant #37.

a. Time in offensive/defensive.

b. Time in location.

Participant #38.

a. Intelligence.

b. Communications.

c. Weather.

Participant #39.

a. Length of engagement.

b. Weather.

c. Support status.

d. Frontages.

Participant #40.

a. Status of adjacent corps.

b. Weather/terrain.

c. Type of corps/division. For example, a light division in NATO does not attack.

Participant #41.

a. Terrain.

b. Type Blue units.

c. Enemy intentions.

d. Supply status (Blue ammo, POL).

Participant #42.

a. Readiness posture of division/corps.

b. Type corps/mechinized or light.

c. METT-T.

Participant #43.

a. Anticipated success of forces currently engaged.

b. Force structure for follow-on missions next 3-5 days.

c. Capability of corps to logistically sustain additional forces.

Participant #44.

a. What are we supposed to be doing as a corps (regardless of status)?

b. Momentum. Are we presently advancing? Going back? Winning? Losing?

c. Status of logistics and supplies.

d. How far can I see (intelligence)?

e. Communication status.

f. Weapon strength.

g. Personnel strength.

h. Morale.

Participant #45.

a. Weather.

b. Combat service support (CSS).

c. Morale.

Participant #46.

a. Status of corps on left and right (engaged/not engaged).

b. The addition of adjacent corps is vital because an aggressive commander of a corps may request to attack when the parent army is defending. For example, if the corps on the left is engaged, but the subject corps is not, perhaps he could attack into the flank of the enemy.

Participant #47.

a. Days of sustained combat.

b. Battlefield air superiority.

Participant #48.

a. Location of army objective line most important.

b. Combat effectiveness of corps/division is important.

Participant #49.

a. Ability to support logistically.

Participant #50.

a. Log status/readiness of corps/division.

Participant #51.

a. Status of adjacent units.

b. Duration of engagements at point of decision.

c. Status of air support.

d. Status of artillery support.

e. Status of logistical support.

f. Status of combat support units.

DEGREE OF REALISM

Participant #1.

a. In today's world, I cannot imagine the US Army engaged in a war, having a corps in reserve--maybe two divisions--but not a corps.

b. Re #L--As an Army commander, I do not give a damn about a line. In combat I want to attack, to take away the initiative of an enemy; so I will attack it and change the "phase line".

Participant #2.

d. An entire corps in reserve would not normally be engaged--portion of the corps might be engaged with light forces.

e. Normally, not more than 1 corps (at most) would be in reserve.

l. Not sure what this means--if it is the Army's objective for the operation than it is a real world variable.

m. Normally the entire Army would have one posture--some portions would be attacking, another defending, etc.

Participant #3.

Some ratios from battle reports during historical engagements should be used.

Participant #4.

Your echelonment terminology is vague for US doctrine, and seems unusually "Sovietized".

k. This could happen, and is likely to be reported or become evident in lack of reporting on having hit certain checkpoints. It can be partially solved by "priority of route" orders or instructions to the obstructing corps, to get the hell off the roads and out of the way.

Participant #5.

1. I am not certain what corps in reserve has to do with assignment of division?--maybe it should read divisions in reserve?

2. Corps in reserve usually not engaged.

3. Term objective phase line does not have meaning.

Participant #6.

e. Operations order to corps presumably states posture of parent army. Not sure corps commander need to know number of corps behind. If army has given mission and resources to accomplish, he goes to it.

n. Op ord ought to tell.

Participant #7.

a, e, f, h. It is my belief that having corps in reserve is a figment of the imagination.

Participant #8.

f. Echelonment is foreign to US vocabulary--it is a threat term.

i. See above.

j. Reserve division committed.

Participant #9.

Does the US Army now use the term echelon?

Participant #10.

c. Historical studies plus several computer simulations with different players each time.

i. Factor of model play as controlled by c.

k. See c.

m. Factor of game play; see c.

n. Factor of game play; see c.

o. Factor of model parameters, requires careful discussion and evaluation of historical results.

Participant #11.

f. Mission and location.

o. BDA's and unit status report; however, capability is the key assessment--i.e., combat forces and casualties + CSS status, LOC condition, etc.

Participant #12.

k. Actual cause of delay for an adjacent corps is not as critical as the delay itself.

Participant #13.

a. Do not expect the war to last long enough to have the luxury of a corps in reserve?

e. Same as a.

f. Same as a.

Participant #14.

m. Parent army's subordinate corps may be conducting completely different operations (ATK, DEF, etc.) at same time.

Participant #15.

A corps would not be in a 2d or 3d echelon. It would be committed or not committed to a combat mission.

Participant #16.

g. You can not have too much artillery. If it is here, use it!

Participant #17.

Some would be available--friendly hopefully. Overall strategy, status of adjacent units, etc., should be known at minimum.

Participant #18.

Provide army commander's concept; e.g., the campaign plan is to attack when army gains superiority in sector, or the campaign plan is to defend along line indefinitely, etc.

Participant #19.

Are you asking about US or Russian units? Echelon--Reserve?

g. Real world data is available.

Participant #20.

Do not understand question.

Participant #21.

Use available intelligence to determine potential for combat of enemy forces.

Participant #22.

a. Available individual replacements; arrival of POMCUS units.

e. Same as above.

f. Mission statement.

g. Currently fixed.

j. EEI--tough one to know.

m. Mission statement.

p. Mission statement.

Participant #23.

Difficult to develop based on understanding of capabilities and organization of threat. Not always a simple 1:3 or 3:1 ratio in effectiveness.

Participant #24.

As you can probably surmise, I do not understand this question. In any case, terminology is the biggest "artifact" problem.

"Echelon"---? (on-line or reserve (Only?)).

"Posture" should be "mission' (your description is its current activity, which may or may not be its mission).

Support status =? (strength?)

Participant #25.

a. Likelihood of US corps in reserve is remote.

b. All corps would be engaged soon.

Participant #26.

Information may be available to army commander which is not immediately available to corps or division commander. Information deemed necessary to the lower echelon commanders will normally be surmised thru the respective staff estimates and the forecasts from higher HQ as available.

Participant #27.

Corps force ratio--talk to corps commander and find out what he is facing (from his intelligence/combat reports).

Participant #28.

One cannot help but be driven mentally to the Europe scenario--this intensity of combat at this level is just not realistic at any lesser level of intensity. And in Europe, its all up front to defend, with even those forces not sufficient in all areas; i.e., it's a one-echelon defense. The only reserves are on the TPDFL.

Participant #29.

In a heavy, medium- to high-intensity fight in Europe, everything with be committed, at least initially. We'll be lucky to have one reserve division per army (e.g., CENTAG)--reserve corps will not be available for some time, if ever.

Participant #30.

Experienced senior commander judgment--areas probably cannot be quantified or extrapolated except for academic purposes.

Participant #31.

Term echelon has no meaning.

Participant #32.

Reports, forward observation, aerial observation or electronics detection.

Participant #33.

Concept of operations.

Participant #34.

i. Status reports.

DEGREE OF UNCERTAINTY

Participant #1.

Try to obtain more info but don't spend too much time doing it.

Participant #2.

Situationally extrapolate data.

Participant #3.

Operate in conservative manner until as much information as possible was acquired.

Participant #4.

Best-guess estimate, information followup; be prepared to change earlier decisions.

Participant #5.

First I would seek confirmation of information, best-guess at decision point. Where I wasn't creating the battle's "focal" point, I would have to be absolutely sure that I needed to commit reserve division(s). This commitment would bring out my "conservative side"--desperate straits before I would release it/them.

Participant #6.

Plan worst case in resolving uncertainties. Take aggressive action and do not wait for the situation to improve on its own.

Participant #7.

In general, most data will be uncertain (Clausewitz "fog" of war). Always attempting to get more information. Some uncertainties (nuclear weapons use) will cause more conservatism; some will allow boldness; and best-guesses will be constant. If there were a formula for this, war would indeed be a science and not an art.

Participant #8.

b. Corps Engagement Status--questions... (1) How heavily engaged--Armor? Infantry? Irregulars? (2) Best-guess if can't know with certainty.

l. Location of Army Objective Phase Line--What is purpose of phase line?--limit advance?--limit withdrawal?

Participant #9.

c. Would best-guess.

k. Would seek more information.

o. Would best-guess.

Participant #10.

I would make a best-guess estimate of the factor.

Participant #11.

My battle management decisions would be affected by all uncertainties. I would insist on obtaining best possible, updated information and status estimates; and, given the overall mission, be prepared to take the necessary risks at the right time and place.

Participant #12.

Force ratios must be estimated based on several factors to include battle reports, losses and templating.

Status of other friendly units and relationships must be judged and measured against "what if" situations, and not merely taken on face value of situation reports.

Participant #13.

Until I obtain more information and intelligence, I would act cautiously--(in a conservative manner).

Participant #14.

j. I am assuming enemy 2d echelon--best-guess.

Participant #15.

Best-guess on basis of intelligence available.

Participant #16.

Don't understand.

Participant #17.

Force ratios will have a degree of uncertainty in any event. Include best estimates and proceed.

Participant #18.

All the above. Information is power and should prove most valuable. Specific information at proper time could turn the battle.

Participant #19.

Sorry, I do not understand the question!

Participant #20.

I would ask for more information.

Participant #21.

e. Unrealistic in our world to have corps behind.

Participant #22.

h. Conservative manner.

c., o. Intell best-guess.

k. More information.

Participant #23.

What is "combat ready"?

Participant #24.

o. Evaluate past performance. Play division conservatively until results come in.

c. Constant update of data to ensure perceived force ratio nolds.

e. Constant update of data, but play corps normally.

h. As e.

n. As e.

Participant #25.

Conservative manner making best-guess estimate.

Participant #26.

Always attempt to keep up-to-date on information; prime the staff for further information. Be prepared to accept considerable uncertainty, but exercise creative visualization of the overall battlefield to anticipate likely (and unlikely) developments; exercise best-guess estimate at critical junctures where something must be decided.

Participant #27.

Information on the above should be obtained rather than best-guessing.

Participant #28.

Probably make a best-guess; however, would probably cause me to act more conservatively.

Participant #29.

l. As an army commander, the objective phase line is not all my doing, but involves a higher HQ and adjacent armies. I need data on these elements to make decisions w/ more certainty.

m. Without an overall posture of my army, I cannot make decisions about my corps.

Participant #30.

Information overload is part of the fog. I would go with best-guess estimate after culling critical data.

Participant #31.

Both force ratios would be based on a best-guess estimate.

Participant #32.

Best guess. Accept risk and execute decisively.

Participant #33.

For programs 1, 5, 7, there is definite need for information concerning the adjacent corps (i.e., force ratio, status, engagement, location regarding army (parent) objective phase line).

Participant #34.

First attempt to gain additional information--then make best-guess estimate.

Participant #35.

Would attempt to gain more information within the bounds of timeliness and mission. At point of decision, I would go with what I had.

Participant #36.

k. Battlefield is fluid.

Participant #37.

Decisions are situational. If time permitted I would attempt to eliminate/reduce any existing uncertainties. If the situation does not permit such luxury, the best-guess estimate would have to suffice.

Participant #38.

Estimating current engagement status, combat worth force ratio and commitment of divisions would be decided on a combination of previous unit actions, currency of latest reported status and commanders estimate of the division commander's ability to fight his division. All would determine the degree of uncertainty that is acceptable.

Participant #39.

For areas of uncertainty I would use real world experience and a best guess.

Participant #40.

Generally, I tend to be more conservative, recognizing that even engagement data (for example) may be out of date and the enemy may have shifted forces into or out of my area of operations.

Participant #41.

Make a best guess.

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EVALUATION MODEL)(U) ARMY CONCEPTS ANALYSIS AGENCY
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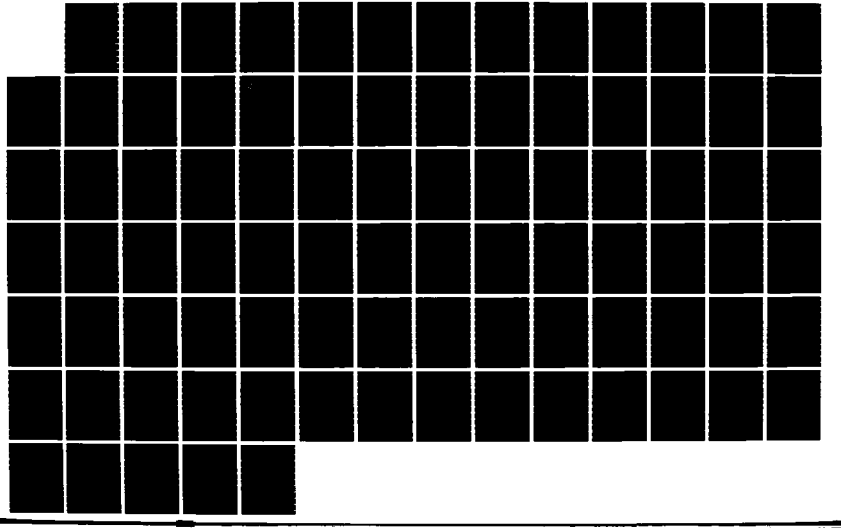

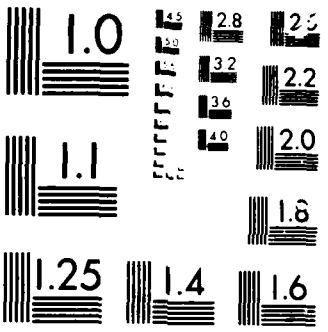
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SCENARIO DEPENDENCE

Participant #1.

1. I assumed that I would coordinate movements with higher HQ and my own corps and did not give a damn about lines!

Participant #2.

Friendly status would be situational dependent.

Participant #3.

Role of the reserve corps would be different in different theaters. For example, in Europe in an all out Warsaw Pact offensive, it would certainly have to be committed, while in SWA you probably would not have a full reserve corps to commit; all limited forces would be online.

Participant #4.

Is this your version of the term "scenario"? If so, it needs to be a geographic variable and set up that way. In a scenario-specific situation, the geography/location would affect decisions.

Participant #5.

d. Depends on terrain and potential enemy forces in area. Example: Korea terrain would slow down enemy advance while northern Europe plains would allow for rapid enemy movement.

Participant #6.

Scenarios will make major different in number, size, and level of units assigned, as well as support available from other services.

Participant #7.

The role/importance would change based on the threat being faced/engaged. The order of battle and threat doctrine would dictate importance. My answers in the experiments were based on a European scenario.

Participant #8.

I believe that all of the above are scenario dependent, and that the relative importance is a function of the theater mission and the specific characteristics of that theater.

Participant #9.

Not sure what you are asking for?

Participant #10.

SW Asia--roles of b, c, d, change rapidly in wider spaced swirling battles. N,O are off and on in hours. Europe and Korea are much more fixed fights with terrain in the form of rivers defining battle lines.

Participant #11.

Clearly, the factors would change depending the scenario. Plains of northern Europe or the mountains of Korea, or the deserts of SWA. Additional intelligence of enemy position. Esprit de corps, combat losses, and other pieces of the scenario must be considered. Also, local militia support (favorable or unfavorable) must be explored. The changes in this scenario have direct bearings on the "values" given to the decision factors.

Participant #12.

A scenario-specific situation would most likely change any of these factors. In Europe, for example, the status of committed forces and reinforcements in high-intensity combat would be very different than that in a low- to mid-intensity environment in SWA.

Participant #13.

The role of these specific factors will certainly be changed in the European scenario by mission, enemy, terrain, time criticality, and morale and status of troops. Terrain is a critical decision factor which will change as a function of different environmental factors.

Participant #14.

The heavier threat in Europe makes ratios and echelons more important. Must keep second operational echelon in mind, plus follow-on forces behind it.

Participant #15.

g. Echelon to which corps assigned. Reserve vs online--the probability of being engaged by heavy forces is greater Europe for reserve forces. SE Asia also has good possibility of reserve corps being engaged by heavy forces.

b. Same answers as above.

Participant #16.

More critical is METT-T.

Participant #17.

I cannot see what this is leading to!

Participant #18.

Unable to answer.

Participant #19.

Terrain, weather (climate), troop training (friendly or enemy) will all impact on each factor and its importance.

Participant #20.

Do not see this as area/terrain dependent. But--what is my mission, strategic objective, etc.?

Participant #21.

A corps can defend more easily in mountainous Korea than attack. Fewer forces are needed, too. A larger reserve may be wanted in SWA than Korea. Force ratio in Europe is more critical.

Participant #22.

Intensity of combat, enemy forces, and friendly intent.

Participant #23.

Depth of the battlefield in terms of terrain would influence how much risk you would take in allowing a corps in a favorable attack posture to go beyond an army objective line in order to take maximum advantage of maneuver against the rear echelons of an enemy force.

Participant #24.

Force ratio status would be affected by air status especially in Europe where bad weather may reduce effectiveness of Red air. Partially true also in Korea; not at all true in SWA.

Participant #25.

Very little.

Participant #26.

d. 1. A Korean scenario would depend upon tactical disposition of forces as determined by terrain.

Participant #27.

Terrain will dictate different allocations of forces in these regions. You want as many forces online and in contact as terrain and enemy status permits/dictates.

Participant #28.

Factor of METT-J.

Participant #29.

Factors of METT-T must be applied at all levels of command. The employment of resources depends upon the commanders analysis of these factors. Parameters are established to trigger a need for a decision but a look at all factors must be made before the decision is made.

Participant #30.

d. Terrain drives battle decisions so much that a map is essential for location/posture decisions.

1. Distance, terrain, plus time marked here. Need this data.

PROTOTYPICAL SITUATION

Participant #1.

Central European scenario with more than the on-line corps considered, additional POMCUS divisions and NATO divisions are forward.

Participant #2.

Need to put into a scenario to make the responses more meaningful.

Participant #3.

While the "experiment" expands beyond mindless computations of force ratio in the decision process, I am fearful that you are trying to discover a cookbook for corps commanders--and hopeful that they will reject such nonsense. I cannot emphasize enough how important the mission is to decision process. Windows of opportunity for commanders, based upon "what's happening" or might in 48, 72, 96, hours can't be slammed shut by mathematical formula. This experiment did not (nor can others) model the human dimension of these decisions.

Participant #4.

Yes--from my limited experience in tactical maneuvers, NTC scenarios came to mind. I had to expand from battalion-task force scope to corp/army level.

Participant #5.

Yes--In planning combat support and combat service support systems to support the fighters, prototype situations (defend, attack, delay, etc.) and distances and time come to mind.

The MAP is key, but some of these prototypes elements such as defend, attack, distance, engaged, etc. make the preliminary decisions easier.

Participant #6.

No prototypical situation comes to mind.

The conditions considered typify the thought process, although not normally in the specific manner described.

Participant #7.

Yes--The execution of an armored division's GDP in VII Corps in Europe.

Participant #8.

The European theater comes immediately to mind.

Participant #9.

No! Need refinement.

Participant #10.

Defend in Europe outnumbered!

Participant #11.

We assume a steady influx of C^3I and its processing use are steady. Info overload is a bogeyman.

Participant #12.

I lack the experience at corps and echelons above corps to make any constructive comments here.

Participant #13.

European.

Participant #14.

Europe came to mind; i.e., marginal weather, long visibility lines, mechanized formations and large forces. Decisions were made very quickly with fairly limited information, somewhat realistic.

Participant #15.

Northwest Europe. German Eastern Front WW2. Thick operations with proximities to reinforce success by the imposition of combat power.

Participant #16.

I felt my decisions were swayed toward the European scenario. Emphasis within the Army sways all thinking toward Europe and current deep-attack doctrine.

Participant #17.

The scenario which came to mind was a conventional battlefield in Europe. The "Fulda Gap" scenario relate to the decision process used by me in the experience.

Participant #18.

Scenario seems purely a NATO/WARSAW Pact confrontation.

Participant #19.

None comes to mind.

Participant #20.

Whether enemy is Soviet, 3d world or other power.

Participant #21.

I envision a mechanized corps in the European theater engaging a Soviet force of equal size.

Participant #22.

Given the wide spectrum of geographic areas where the US Army possibly can be employed in the mid- to high-intensity operations, our decision process is a function of training in the European setting. If this in fact the case, a general setting should be presented at the outset. Example--the risk associated with a reserve corps which is engaged at a friendly/enemy ratio is higher in the faster pace mech battlefield than the low- to mid-intensity nonmechinized scenario such as Pacific Theater Operations during WWII. Net allocations of CAS/CSS would change where a higher risk is associated.

Participant #23.

Echeloning has no meaning. Questions difficult to answer without a feeling of the flow of initiative, overall long range intent (strategic/operational), and the unit coherence of the forces.

Participant #24.

What do you do with late arriving forces in Europe if the war has started? Do you really want to throw a newly arrived division into a corps (reserve or online) that is engaged, regardless of the force ratio? The only situation is if survival of the whole army is at stake.

Participant #25.

One more time--what do I want to accomplish? Strategic defense of specific territory--destruction of a military force--seizure of an area? Other factors: combat power ratio sustainability.

Participant #26.

No specific scenario or situation; but literally hundreds of cases, all slightly different.

Participant #27.

A number of 1950-53 Korean War scenarios come to mind; a few from Vietnam.

Participant #28.

Tendency was to be as aggressive as prudently possible--mostly defending at 1:3 and at least defending if not attacking at 1:1 or 3:1. Dependent on criticality, stage of battle, etc.--given more data, weather, terrain, etc.--I occasionally attack at 1:3 if surprise could be achieved. A protypical scenario does come to mind. I once ran a convoy down a completely VC held road that had not been used by US for 4 years. Successfully (since they were the sole users we did not worry about mines!). I would only do that once however. There is applicability. A Soviet who perceived he in fact had 3:1 superiority in the attack (though he tries for 5 or 6:1) certainly would be prepared to defend. Generally, these decisions can be "canned", but a delphi factor (and sometimes a big one) must be cranked in.

Participant #29.

1. Cannot believe there would be a situation where we would not know the unit's mission and amount of internal fire support it possessed.

2. Given only information presented I tended to be more aggressive--anytime had 3:1 odds I tended to attack if the Army was doing anything but delay.

3. I tended to think in terms of European environment and terrain when considering scenarios.

Participant #30.

I put the decisionmaking process in the European scenario, specifically V Corps. Regarding CSS I feel support of engaged units is most important; in priority attacking units, defending units, and delaying units. I put high priority on units reconstituting in the rear.

In placing artillery I put it where it is needed to fire most--never keep it in reserve. Heaviest support to the attack. V Corps has little ground it can give up before the path is open to Frankfurt and the Rhine so all support possible should be put to assist the defense and assure success on the offense.

The corps posture was most difficult. WINTEX last year put us through similar situations and it was difficult to know what CENTAG was doing and what the plan was beyond 96 hours. Good exercise.

Participant #31.

The selection of a corps posture was more easy to envision and conceptualize than the assignment of a new artillery unit based on my knowledge of current war plans and specifically the European theater.

If one postulates that a European war would erupt, with adequate warning signs, to begin the necessary reinforcement and mobilization, and that reinforcement corps would be available, then the decision, on where and how to employ the corps would be a function of what point in the war we are in. Battle management decisions based on METT-T would largely dictate our actions and could very well be based on the variables considered in this experiment.

I find it difficult to envision an artillery unit not being assigned to a division or corps artillery from the outset, i.e., artillery is not held in reserve.

Participant #32.

Yes, the battalion management scenarios taught at Ft. Leavenworth.

Participant #33.

Company and battalion ARTEPX in Europe came readily to mind, and I envisioned corps activities using that analogy.

Participant #34.

I guess the thing that comes to mind is an army group operating in Europe against the classic Warsaw Pact all-out conventional attack. Only in that scenario are you going to encounter the situations described in my mind.

In general, I thought the test did not provide enough information on each scenario or situation. The modern commander is saturated with multiple data upon which to base a decision of the type described here.

Participant #35.

Hell, I am working my way from active defense to AirLand battle in an army that is rapidly modernizing. The Russians/enemy will always have the advantage of the initiative. I will always try to take that away from him. ALB gives me that opportunity as does the combat power being generated from new systems being fielded.

Participant #36.

Yes--Assignment of priority of fire. Based on mission, status, commanders estimate, a particular unit is assigned priority of artillery fires. That is, we will answer that unit's calls first.

Participant #37.

The major concern in the CSS battle management decision is the underlying assumption, given the condition of an engaged reserve, that the situation is critical, assuming no other corps in reserve. At this point, CSS to all elements is paramount to preclude catastrophic consequences.

Participant #38.

Based on my professional education and "always facing the Soviets in Europe," the European scenario came to mind. The answer is yes, because your scenario left so much to my imagination.

Participant #39.

Only one comment--when making decisions at corps or above, all aspects (forces) in the conflict must be considered, since it is a given that the Army will not fight any war by itself.

Participant #40.

AFCENT scenario comes to mind where current reserves and their location are a constant factor to be considered both in defense and in the main attack. Example: In Europe where Warsaw Pact makes 2 or 3 main attacks, you must determine where his reserves (follow-on forces) are and where your reserves are.

OTHER COMMENTS

Participant #1.

At the risk of showing my ignorance, it seems that the 112 situations in the battle management decision to assign a division were repetitious. I felt I was repeating my decisions.

Participant #2.

1. There was not sufficient data on which to make decisions.

2. Decisions relating to army objective and corps posture could only be made if mission of corps in relation to army mission is known.

3. Priority of CAS & CSS could only be meaningful given corps mission and enemy threat (force ratios).

4. Without knowing status of supply of corps, meaningful decision on priority of supply could not be made.

Participant #3.

This model is asking the user to assign missions to a corps--however, not enough information is given on the higher level campaign plan to make such a "mission" decision.

Participant #4.

I'm not comfortable with what I did--not sure that I fully understood what answer you really wanted to get.

Participant #5.

As an Air Force type, I'm not sure the information has any value--I suspect not much. May want to disregard my input.

Participant #6.

The decision model as prototyped does not provide some other basic information required for effective decisionmaking.

Participant #7.

More thorough introduction to testing is needed.

Requirements/terms need to be clearly defined.

Participant #8.

Would help to identify a benchmark for first question. In exercise at beginning, my value for the first question was zero. Subsequent questions and solutions were even less critical. However, I could not assign a lower value.

Participant #9.

I had a vague idea of what I was doing using the computer--but this questionnaire has me completely befuddled, and there does not seem to be anyone present to answer our questions.

Participant #10.

Could be used as an excellent teaching aid, but a preferred response (answer) to each question would be necessary. Best to play in a particular scenario.

Participant #11.

This is a waste of time and money! When I think of all the programs in the Army which have not been funded or which have been billpayers so we can do these kinds of things, I am incensed!

Decisions as done in the model(s) are made by commanders (humans) who measure hundreds of variable which you can never capture nor weight in a model--i.e., strengths and weakness of subordinate commanders, value of terrain and good tactics, etc.

I am not anticomputer, but they have a role in information management not in this kind of decisionmaking for the running of scenarios. It would be a garbage-in/garbage-out drill and I am afraid important decisions in Army are too often made on garbage data.

Participant #12.

I found this exercise frustrating and worthless.

This experiment was the biggest waste of time I have engaged in in my 21 years in the Army.

Participant #13.

I may not have understood the question or assignment of corps.

Participant #14.

You must consider your logistics support.

Participant #15.

Trying to reduce subjective decisions to objective decisions is difficult at best. Taking answers and using them as standard with limited information to start decreases the validity of the answer, even it comes out with a good number and a small standard deviation for a large sample size of random volunteers.

Participant #16.

Ratio of 1 corp FA bn/Div is the best the scenario got. In fact, we doctrinally operate at 1 FA Bde/Div 1 FA Bde = 2-4 FA bns. Therefore, all situations required a pretty high degree of criticality.

Participant #17.

Your questionnaire seizes on too simple aspects of the overall problem. You could set the form parameters of:

ATTACK DEFEND DELAY WITHDRAW

then the engagement/nonengagement, then the force ratio; and set up your specific questions within those 3 parametric forms, looking for criticality issues against specific battle management factors.

Not enough information for many questions to derive valid and reliable results from your respondents.

Participant #18.

Good ideas, but much work needs to be done.

Participant #19.

Some background (read-ahead material) and/or a "take home" exercise describing the purpose of this endeavor and providing more details which could be digested prior to answering the computer questions and this data collection exercise would, perhaps, provide CAA with more meaningful input.

Participant #20.

The artificiality of the data available to the decisionmaker bothers me. The terms "Army Objective Phase Line" is a non term. Phase lines are used to control portions or phases of an operation. So using that term indicated a phased operation with actions either preceding or following.

What leaders (or simulated leaders) were being asked to decide these questions?

Phase lines can be changed where a situation arises that odds are favorable for attack (3:1) or revised rearward where overwhelming odds are encountered.

Participant #21.

The computer "trials" probably brought out my biasses mainly as "force-ratio" requirements--as I remembered them from my infantry school days. Understood what BMD #2 was leading to; somewhat confused about purpose of BMD #5. The added, written part (here) left me more confused about the purpose of it all.

Participant #22.

I wonder if this approach to investigation of pertinent factors will bear and substantive fruit? Could be validated in any way? Could be use credibly to support operational decisions?

Participant #23.

Your terminology needs to be brought in line with Army terms. We do not use echelons or postures. What is an Army objective phase line? The personnel conducting the test seemed vague about the model and the test. That's embarrassing to CAA!!

Participant #24.

I get the impression that these rules are a continuation of our reliance on ratios determine outcomes because of our inability to model combat above the level of one-on-one engagements.

Participant #25.

Exercise is not beneficial in my opinion. It is limited in scope and opinion oriented based upon one's own perception of what situation is.

Participant #26.

It would be interesting to see the consolidated results.

Participant #27.

Difficult to provide best answer without the availability of additional parameters.

Participant #28.

I was often confused as to the location of reserve corps. I did not know what was meant when you had a corps in reserve and you had the decision to make on the importance of another reserve corps. Did we double-stack or assume the original reserve corps would deploy?

Participant #29.

In first simulation (online corps and reserve assignment), it was confusing not to know status of army, e.g., how many corps were already in the army including or excluding the one in reserve. In the CAS assignment situation, the notion of 3d echelon (refurbishment) was totally foreign to my experience. I was unsure what the situation of 3d echelon was meant to convey.

Participant #30.

The scenarios chosen were too simplistic and lacked sufficient detail.

Engaged--ammo resupply 100 critical.
Refurbishment--maintentance support 100 critical.

Conclusion: resolution not fine enough for valid decisions. Too much missing data.

Participant #31.

When an individual is asked to allocate CSS, CAS, etc., it depends on whether or not the follow-on echelons (Blue/friendly) are being engaged in a deep battle/rear battle scenario, or if an attrition battle (old style planning/doctrine) has worn down or warn away 1st and 2d echelon forces.

Participant #32.

There are many more factors that come to mind in making decisions. I tried to keep those out of mind when making decisions on this exercise.

Participant #33.

I honestly believe my input will be of little value due to a lack of understanding of what this drill was all about.

Participant #34.

Questions/situation too general for specific without having other information; e.g., enemy status, other units (left/right flank), reserves. Would do better at answering question with some general background information.

APPENDIX F

SUMMARY OF QUANTITATIVE RESPONSES TO QUESTIONNAIRE

This appendix contains a summary of the quantitative responses of subjects obtained from administration of the questionnaire of Appendix D. This summary is a product of the US Army Research Institute for the Behavioral and Social Sciences (ARI), the developer of the questionnaire.

CAA-SR-86-5

DEPARTMENT OF THE ARMY
US ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VIRGINIA 22333-5600

May 9, 1986

REPLY TO ATTENTION OF

Systems Research Laboratory

Dr. James J. Metzger
U.S. Army Concepts Analysis Agency
8120 Woodmont Avenue
Bethesda, Maryland 20814

Dear Dr. Metzger:

We have now completed the initial examination of the FORCEM questionnaire administered to students from the U.S. Army War College as part of your experimental investigation of decision rules. The following observations and data are provided for your consideration and incorporation into the final study report.

Background

As you know, our interest in this project centered around gaining a better understanding of how military officers approach various battle management decisions. Like you, we wished to determine the relative influence of different FORCEM variables on each type of battle management decision. In addition, however, we were interested in determining the adequacy of these variables for representing real-world combat situations. That is, does the representation of battle management problem in FORCEM consistently match the training and experience of the military subjects. Here, significant deviations from real-world experience might indicate the need for modifications to the way in which information is provided to model gamers.

Other questions of interest in this experiment included (1) how consistent are the derived regression weights with the subject importance beliefs, (2) what additional variables were considered important, (3) how uncertain were different variables believed to be under real-world conditions, and (4) how scenario-dependent were different variables believed to be.

Findings

(A) Relative Importance of Independent Variables Descriptive statistics were generated on the responses provided by the military subjects and are summarized in Table 1. From these data it is noted that there is a great deal of consistency between the average subjective ranking in importance of the independent variables and the regression weights derived from your quantitative analysis. For example, four out of the top five subjectively-ranked variables appear as significant main effects in each of the regression equations:

- Corps force ratio
- Corps engagement status
- Echelon to which Corps is assigned
- Corps location and posture

Other main effects selectively appearing in individual regression equations (ratio of artillery to divisions and echelon to which division is assigned) can be attributed to the specific nature of those decisions.

One should be cautious, however, in viewing the average subjective ranking data from this experiment. Again from Table 1 it is noted that most of the independent variables have a fairly large variance in importance across the military population. What this implies is that consideration of a particular variable tends to be very idiosyncratic --varying with both the decision and the individual. For example, for the top three main effect variables, the following distributions of beliefs were obtained:

	Importance		
	High	Moderate	Low
Corps force ratio	64	10	2
Corps engagement status	58	13	5
Echelon to which Corps is assigned	37	30	9

From the written comments obtained from the subjects, we identified six additional areas of information thought to be important in the battle management process. These areas of information, rank-ordered by their frequency of being mentioned, include the following:

- Availability of combat resources / combat strength
- General assessment of the battlefield situation
- Quality of combat resources / readiness / morale
- Terrain / weather / mobility factors
- Strategy / military objectives / assigned mission
- Status of enemy forces
- Availability of intelligence assets / communications

For the future, you should give consideration as to how these types of data can be realistically provided to the gamer/decisionmakers.

(B) Realism of Independent Variables

A number of the independent variables were viewed as being somewhat artificial or artifacts of the mathematical representations in FORCEM, as indicated by the mean realism scores in Table 1. It is recommended that, for the future, you consider how certain variables (say, those with a mean realism score below 0.85) be represented to gamers/decisionmakers in a more realistic manner. These variables include the following:

- Corps force ratio
- Division combat worth force ratio
- Echelon to which Corps is assigned
- Corps status and number of Corps behind
- Number of Corps in reserve
- Have 2nd echelon divisions been committed
- Number of combat ready divisions in 1st, 2nd echelon
- Ratio of current artillery to current divisions
- Echelon to which division is assigned
- Support status of reserve Corps

Two particular issues frequently noted in the written comments were (1) the term "echelon" has no valid meaning with reference to U.S. forces and (2) it was hard to imagine a situation in which the theater commander would have the luxury of holding an entire Corps-size unit in reserve. These comments potentially explain the low realism scores for those variables which make some reference to either echelon or reserve forces.

The low realism scores of the two "force ratio" variables are possibly due to the difficulty of translating this type of mathematical term into precise real-world examples or illustrations.

(C) Degree of Uncertainty

Military officers realize that they will have to deal with some degree of uncertainty in their available information during wartime. From Table 1 it is noted that a number of the variables have a fairly high degree of uncertainty anticipated with them. These include

- Corps force ratio
- Division combat worth force ratio
- Have 2nd echelon divisions been committed
- Number of combat ready division in 1st, 2nd echelon

- Is on-line Corps holding up advance of adjacent Corps
- Support status of reserve Corps

A slight degree of correlation (r = 0.329) is noted between the realism rating and uncertainty rating for division combat worth force ratio. However, it is not possible to ascertain whether the realism rating had any influence on the uncertainty rating for this variable. Nothing in the written comments would suggest any subjective connection of these two ratings. On the other hand, ratings of realism and uncertainty for Corps force ratio were generally uncorrelated (r = 0.154).

Written comments suggest two prevalent strategies for coping with information uncertainty: (1) making a "best guess" estimate of the situation or specific variable and (2) taking a more conservative approach to planning and decision making. This would suggest that future employment of the FORCEM model ought to give some consideration to treating information uncertainty as an independent variable so that its impact on battle management strategy can be more accurately assessed.

(D) Scenario Dependence

Data from Table 1 suggest that a considerable number of the variables are viewed as being moderately scenario-dependent. That is, the officers rated their relative importance to different decisions as being dependent upon whether or not a European, Korean, Southwest Asian, etc scenario was being considered. This finding suggests that (1) consideration be given to using different regression weights for specific theaters of operation and (2) future experiments on

knowledge elicitation provide a specific context for each battle management decision.

Sincerely,

Dennis K. Leedom
Assistant Director, Systems
Research Laboratory

Independent Variable	Importance Mean	Importance Std Dev	Degree of Realism Mean	Degree of Certainty Mean	Scenario Dependence Mean
Corps Force Ratio	2.82	0.453	0.84	0.63	0.67
Corps Engagement Status	2.70	0.589	0.96	0.85	0.47
Division Combat Worth Force Ratio	2.45	0.773	0.76	0.56	0.62
Echelon To Which Corps Is Assigned	2.37	0.690	0.70	0.91	0.49
Corps Location and Posture	2.36	0.605	0.92	0.90	0.61
Division Engagement Status	2.34	0.793	0.95	0.77	0.63
Current Posture of Corps' Parent Army	2.29	0.649	0.86	0.80	0.49
Corps Status and Number of Corps Behind	2.24	0.709	0.73	0.83	0.45
Number of Corps in Reserve	2.18	0.828	0.80	0.86	0.58
Have 2nd Echelons Been Committed	2.15	0.860	0.81	0.68	0.59
Location of Army Objective Phase Line	2.13	0.618	0.86	0.83	0.61
Number of Combat Ready Divisions in 1st, 2nd Ech	2.12	0.879	0.77	0.73	0.48
Ratio of Current Artillery to Current Divisions	2.04	0.840	0.85	0.78	0.61
Echelon to Which Division Is Assigned	2.00	0.800	0.76	0.77	0.53
Is On-Line Corps Holding Up Advance of Adj Corps	1.84	0.767	0.88	0.59	0.59
Support Status of Reserve Corps	1.82	0.743	0.84	0.70	0.42

Degree of Realism 1.00 = Real-world Data 0.00 = Artifact of Simulation Model
Degree of Certainty 1.00 = Hard Data 0.50 = Moderate Uncertainty 0.00 = Unknown
Scenario Dependence 1.00 = Scenario-specific Variable 0.00 = Context-free Variable

TABLE 1

APPENDIX G

PILOT EXPERIMENT

This appendix contains data supporting the pilot experiment documented in Chapter 3 of the main report.

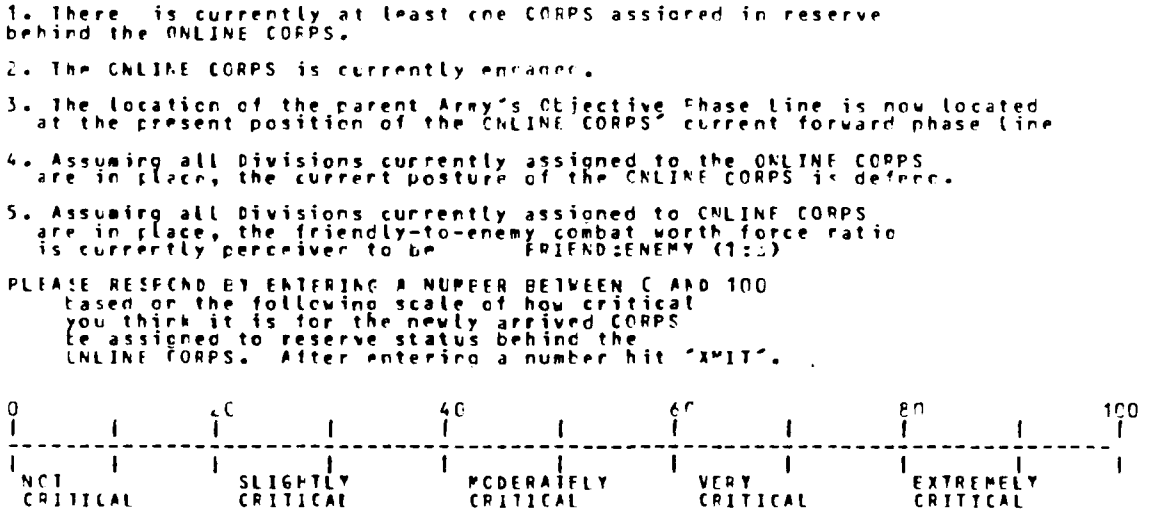

Figure G-1. Sample Question

Table G-1. Cell Means - Pilot Experiment

A	B	C	D = 1	2	3	4	5	6
1	1	1	31	36	43	43	65	91
		2	13	18	25	18	25	48
	2	1	36	45	62	55	67	96
		2	19	22	33	28	34	58
2	1	1	13	20	25	27	32	78
		2	6	9	17	9	18	31
	2	1	18	31	30	38	43	79
		2	11	13	15	15	18	40

Grand mean = 34

Table G-2. Marginal Means - Pilot Experiment

Factors	Levels					
	1	2	3	4	5	6
A	42	26				
B	31	38				
C	46	23				
D	18	24	31	29	38	65

Grand mean = 34

Table G-3. ANOVA Table - Pilot Experiment

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Level of significance
A	1	26,696	26,696	43.05	**
B	1	5,084	5,084	6.13	*
C	1	59,127	59,127	131.10	**
D	5	98,885	19,777	36.35	**
AB	1	203	203	1.73	
AC	1	1,649	1,649	16.71	**
AD	5	1,010	202	1.32	
BC	1	118	118	1.47	
BD	5	222	44	0.29	
CD	5	10,023	2,005	6.52	**
ABC	1	78	78	0.37	
ABD	5	469	94	0.71	
ACD	5	951	190	1.34	
BCD	5	667	133	1.14	
ABCD	5	345	69	0.47	
T	8	48,974	6,122	79.73	**
AT	8	4,961	620	8.08	**
BT	8	6,580	823	10.72	**
CT	8	3,608	451	5.88	**
DT	40	21,764	544	7.09	**
ABT	8	938	117	1.53	
ACT	8	790	99	1.29	
ADT	40	6,115	153	1.99	*
BCT	8	643	80	1.25	
BDT	40	6,098	152	1.99	*
CDT	40	12,290	307	4.00	**
ABCT	8	1,695	217	2.76	*
ABDT	40	5,304	133	1.73	
ACDT	40	4,131	103	1.35	
BCDT	40	4,697	117	1.53	
ABCDT	40	5,815	145	1.89	*
Error	36	2,763	77		

*Significant at the 0.05 level of significance.

**Significant at the 0.01 level of significance.

Table G-4. Comparison of Models - Pilot Experiment

REGRESSION MODEL PREDICTED VALUE AND PRIORITY		CELL MEAN CRITICAL INDEX AND PRIORITY		PRESENT FORCE% PRIORITY	NUMBER CORPS IN RESERVE	ENGAGED	FORCE RATIO FRIEN	POSTURE	LOCATION
1	99.46	1	96.22	1	0	YES	1:3	ATTACK	FORWARD
2	92.60	2	91.44	13	0	NO	1:3	ATTACK	FORWARD
3	79.83	3	79.33	25	1	YES	1:3	ATTACK	FORWARD
4	72.97	4	77.89	37	1	NO	1:3	ATTACK	FORWARD
5	64.67	5	67.11	3	0	YES	1:3	DEFEND	FORWARD
6	57.81	6	65.00	15	0	NO	1:3	DEFEND	FORWARD
7	54.45	9	54.56	5	0	YES	1:3	DELAY	FORWARD
8	53.06	7	62.11	7	0	YES	1:3	DEFEND	REACHED
9	52.69	8	58.44	2	0	YES	3:1	ATTACK	FORWARD
10	47.08	12	43.44	17	0	NO	1:3	DELAY	FORWARD
11	47.00	14	43.33	19	0	NO	1:3	DEFEND	REACHED
12	46.63	10	47.89	14	0	NO	3:1	ATTACK	FORWARD
13	45.48	11	44.56	9	0	YES	1:3	DELAY	REACHED
14	45.04	13	43.44	27	1	YES	1:3	DEFEND	FORWARD
15	41.98	15	40.00	26	1	YES	3:1	ATTACK	FORWARD
16	38.62	17	35.89	21	0	NO	1:3	DELAY	REACHED
17	38.18	21	32.44	39	1	NO	1:3	DEFEND	FORWARD
18	37.57	18	35.67	11	0	YES	1:3	WITHDRAW	REAR
19	35.02	22	31.11	38	1	NO	3:1	ATTACK	FORWARD
20	34.92	16	37.78	29	1	YES	1:3	DELAY	FORWARD
21	34.23	25	30.00	31	1	YES	1:3	DEFEND	REACHED
22	33.82	19	34.44	4	0	YES	3:1	DEFEND	FORWARD
23	31.18	24	32.56	8	0	YES	3:1	DEFEND	REACHED
24	30.71	24	30.56	23	0	NO	1:3	WITHDRAW	REAR
25	27.95	27	26.78	41	1	NO	1:3	DELAY	FORWARD
26	27.37	28	24.78	43	1	NO	1:3	DEFEND	REACHED
27	26.65	29	25.33	16	0	NO	3:1	DEFEND	FORWARD
28	26.18	26	28.44	6	0	YES	3:1	DELAY	FORWARD
29	25.85	29	30.67	33	1	YES	1:3	DELAY	REACHED
30	25.40	31	22.33	10	0	YES	3:1	DELAY	REACHED
31	24.32	29	25.11	20	0	NO	3:1	DEFEND	REACHED
32	23.03	32	17.78	28	1	YES	3:1	DEFEND	FORWARD
33	21.39	33	19.00	12	0	YES	3:1	WITHDRAW	REAR
34	19.27	40	14.78	32	1	YES	3:1	DEFEND	REACHED
35	19.22	36	18.00	18	0	NO	3:1	DELAY	FORWARD
36	18.89	42	20.11	45	1	NO	1:3	DELAY	REACHED
37	18.04	38	17.78	22	1	NO	3:1	DELAY	REACHED
38	17.04	34	18.11	35	1	YES	1:3	WITHDRAW	REAR
39	16.14	35	18.11	40	1	NO	3:1	DEFEND	FORWARD
40	14.53	44	12.89	24	0	NO	3:1	WITHDRAW	REAR
41	14.37	41	14.67	30	1	YES	3:1	DELAY	FORWARD
42	13.68	42	13.00	34	1	YES	3:1	DELAY	REACHED
43	12.51	39	17.22	44	1	NO	3:1	DEFEND	REACHED
44	11.08	43	13.00	47	1	NO	1:3	WITHDRAW	REAR
45	9.97	45	10.78	36	1	YES	3:1	WITHDRAW	REAR
46	9.81	47	8.56	42	1	NO	3:1	DELAY	FORWARD
47	9.72	46	8.89	46	1	NO	3:1	DELAY	REACHED
48	9.71	48	9.56	48	1	NO	3:1	WITHDRAW	REAR

Table G-5. Prototype Assignment in FORCEM - Pilot Experiment

Online corps	Has res corps	Engaged	Force ratio	Location	Posture	Prd eqn rank	FORCEM rank
#1	No	Yes	3:1	Fwd	Att	9	2
#2	No	Yes	3:1	Fwd	Att	9	2
#3	No	Yes	3:1	Fwd	Att	9	2
#4	No	Yes	3:1	Fwd	Att	9	2
#5	No	Yes	3:1	Fwd	Att	9	2
#6	No	Yes	3:1	Fwd	Att	9	2
#7	No	Yes	3:1	Fwd	Att	9	2
#8	No	No	3:1	Fwd	Att	12	14
#9	No	No	3:1	Fwd	Att	12	14
#10	Yes	Yes	3:1	Fwd	Att	15	26
#11	Yes	Yes	3:1	Fwd	Att	15	26
#12	Yes	Yes	3:1	Fwd	Att	15	26
#13	Yes	Yes	3:1	Fwd	Att	15	26
#14	Yes	Yes	3:1	Fwd	Att	15	26
#15	Yes	Yes	3:1	Fwd	Att	15	26

APPENDIX H

EXPERIMENTAL DATA

This appendix contains the raw data collected as described in Chapter 5 of the main report.

(NOT USED)

Table H-1. Data - Decision 1
(page 1 of 2 pages)

CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MEAN	ST DEV
1111	40	0	50	30	10	10	60	45	40	50	20	30	50	50	60	80	90	40	85	50	44.5	24.1
1112	30	50	40	10	15	50	50	40	60	75	20	45	40	25	60	80	75	50	75	75	47.0	22.0
1113	40	10	30	80	10	30	40	60	80	60	20	100	70	100	60	85	85	60	75	60	55.8	27.5
1114	15	15	20	60	0	30	70	40	90	70	40	50	50	50	70	95	95	40	90	95	64.3	29.7
1115	45	15	10	80	50	50	70	40	80	90	20	30	65	100	60	80	80	30	100	95	63.5	29.7
1116	35	85	60	80	25	90	100	80	100	70	100	100	100	100	59	90	95	70	100	100	81.9	22.6
1121	10	5	10	20	0	20	20	20	40	29	0	60	30	25	40	50	25	50	75	20	27.4	20.0
1122	0	10	10	40	10	20	20	20	30	30	20	20	50	25	70	40	20	60	90	75	33.0	24.4
1123	15	5	20	20	25	20	10	15	40	40	0	45	60	25	60	75	30	40	45	40	31.5	19.7
1124	10	20	10	40	10	20	20	30	50	50	90	50	40	25	60	75	60	50	75	75	43.0	24.5
1125	0	60	50	20	0	20	10	15	40	30	100	75	30	50	70	90	90	50	75	60	46.8	30.7
1126	10	60	60	60	0	100	100	75	70	80	100	70	100	100	60	90	90	80	100	100	76.3	28.5
1131	5	0	20	10	0	10	0	1	20	25	0	20	20	0	20	15	15	40	25	25	13.5	11.4
1132	5	0	10	10	0	20	0	10	10	25	10	45	10	25	40	30	5	50	20	40	18.3	15.7
1133	5	0	0	40	0	10	0	35	20	30	10	20	15	50	40	50	15	50	40	50	24.0	19.0
1134	5	0	10	10	0	10	0	15	20	30	0	10	40	0	30	50	15	50	40	80	20.8	21.8
1135	10	0	20	10	0	0	0	15	30	25	20	10	15	50	40	50	25	30	50	50	22.5	17.9
1136	10	65	10	30	15	20	50	30	50	25	20	50	60	100	40	25	60	70	75	95	45.0	27.0
1211	65	15	50	50	50	30	60	25	60	50	20	50	85	50	80	80	50	60	80	75	54.3	20.3
1212	35	15	10	60	30	30	40	35	40	50	20	50	60	50	60	85	45	50	75	95	46.8	22.0
1213	60	15	30	70	80	70	100	65	60	75	50	45	75	100	70	90	70	60	90	80	66.8	22.0
1214	25	10	50	60	35	40	50	55	90	60	100	70	50	75	80	95	80	50	85	60	61.0	23.7
1215	75	20	50	40	35	30	70	60	70	90	50	50	60	100	70	80	90	50	75	90	64.3	19.9
1216	20	95	70	50	60	90	100	90	70	90	100	70	100	100	80	95	80	80	100	100	82.0	20.9
1221	25	10	50	20	25	10	10	60	30	40	20	45	50	0	60	50	20	60	90	40	35.8	22.6
1222	35	20	40	20	35	20	10	40	30	60	50	50	60	25	60	50	25	50	70	65	40.8	17.5
1223	30	10	40	40	30	20	20	30	30	50	99	45	20	50	70	30	60	50	80	80	44.2	23.6
1224	25	5	30	50	15	20	30	75	40	60	100	45	60	25	60	90	80	50	90	60	50.9	27.6
1225	5	60	50	20	45	20	10	20	40	85	100	20	45	50	60	30	85	50	100	80	47.8	29.6
1226	10	90	50	50	45	100	100	80	100	60	100	100	100	100	70	100	99	80	100	100	81.7	26.0
1231	10	2	20	0	0	0	10	10	30	30	0	20	5	25	40	20	10	50	10	20	15.6	14.1
1232	0	0	0	40	10	20	10	15	30	40	0	20	30	0	40	30	10	50	10	40	19.8	16.6
1233	15	5	10	20	60	10	0	60	30	50	0	45	40	50	30	80	30	40	15	40	31.5	22.2
1234	15	30	20	20	10	10	10	20	30	45	20	20	15	0	30	40	50	50	25	95	27.8	20.9
1235	5	3	20	20	15	0	0	60	50	30	0	10	20	50	60	45	60	70	75	75	33.4	27.3
1236	50	75	30	30	0	40	70	40	60	50	40	50	70	50	70	80	75	70	55	95	55.0	21.8
2111	40	10	20	10	20	20	40	10	70	20	0	10	20	50	60	25	25	30	45	40	28.3	18.4
2112	10	5	30	20	35	70	20	20	20	10	50	60	20	50	40	15	20	30	75	75	31.8	20.6
2113	50	20	20	20	25	10	40	20	20	35	20	60	40	100	60	20	10	30	55	75	36.5	23.7
2114	5	40	20	30	25	40	20	15	50	25	50	30	60	0	70	15	75	30	50	75	36.3	22.2
2115	25	50	10	20	70	10	40	10	40	25	10	40	30	50	40	10	40	30	30	85	33.3	20.3
2116	10	70	40	30	60	100	100	70	90	25	100	45	90	100	40	30	85	40	75	100	64.4	30.5
2121	20	0	0	0	15	10	10	15	0	30	20	10	30	0	30	15	15	40	65	20	17.3	16.2
2122	5	0	0	10	15	20	10	15	10	15	0	20	30	0	40	20	15	40	80	30	18.8	18.9
2123	5	0	0	10	20	20	0	20	10	35	20	45	15	50	40	20	10	40	50	20	21.5	16.5
2124	5	5	0	10	0	0	10	10	20	40	20	10	20	0	30	40	25	50	50	65	20.5	19.5
2125	5	10	30	10	0	30	10	30	40	15	90	10	40	50	30	30	70	40	65	50	32.8	23.8
2126	60	40	0	20	40	40	90	20	10	50	100	70	95	100	60	30	80	60	60	95	56.0	31.0
2131	0	0	0	0	0	0	0	10	10	10	0	10	0	0	40	10	5	20	10	10	6.8	9.8
2132	5	5	0	0	0	0	0	2	10	5	0	10	20	0	10	10	5	20	10	10	6.1	6.3
2133	75	0	0	0	15	0	0	2	0	5	0	45	0	25	20	15	5	20	20	10	12.8	18.9
2134	5	0	0	0	0	0	0	10	10	10	0	20	10	0	20	20	20	30	10	50	10.8	13.0
2135	10	0	10	0	20	0	10	10	10	5	0	30	10	0	10	20	10	40	30	60	14.3	15.5
2136	0	10	0	0	10	20	60	15	40	45	40	30	70	50	30	20	90	60	50	80	36.0	27.1
2211	15	1	0	20	30	10	10	20	30	15	0	70	5	50	20	30	35	50	60	20	24.5	23.1
2212	5	5	0	10	50	10	20	30	30	40	0	50	20	100	60	45	15	50	45	25	30.5	25.0
2213	20	10	20	10	70	20	30	15	20	10	30	50	40	75	20	50	40	40	95	50	35.8	23.6
2214	5	10	10	20	50	20	20	20	50	30	100	50	40	25	40	20	50	20	85	80	37.3	26.4
2215	30	5	40	20	50	20	10	25	10	40	100	45	30	50	30	50	60	40	50	75	39.0	22.9
2216	20	20	50	50	75	100	100	75	90	50	100	100	90	100	60	50	85	70	55	95	71.8	21.2

Table H-1. Data - Decision 1
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CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MEAN	ST DEV
2221	15	3	0	10	30	0	10	30	10	25	0	10	20	0	40	20	45	40	35	25	18.4	14.8
2222	5	20	0	0	20	0	10	30	0	10	0	45	30	50	30	10	20	30	45	50	20.3	17.7
2223	0	5	0	20	30	0	20	20	10	15	20	45	10	25	10	10	15	20	90	30	19.8	20.0
2224	10	45	20	10	25	10	20	10	20	20	99	45	45	0	40	20	50	50	75	80	34.7	26.6
2225	10	5	30	10	55	10	0	15	30	5	100	50	30	25	30	30	45	30	45	90	32.3	26.6
2226	25	60	0	30	40	50	100	85	40	25	100	50	100	100	20	80	50	50	90	95	59.5	31.9
2231	5	0	10	0	15	0	0	10	10	10	0	20	0	0	10	10	10	30	10	10	8.0	7.8
2232	10	0	0	0	0	0	0	15	0	10	0	10	10	0	10	25	10	40	15	10	8.3	10.3
2233	0	0	0	0	10	0	0	25	10	25	0	35	20	0	30	20	10	20	30	10	12.3	12.3
2234	0	0	0	0	20	0	0	10	10	10	20	20	15	25	10	15	25	40	10	10	12.0	10.8
2235	10	40	10	10	25	0	0	10	10	20	0	20	5	50	10	30	50	40	50	50	20.0	18.6
2236	0	0	0	10	25	30	50	15	10	15	10	20	50	25	30	30	25	50	75	75	29.3	21.7
	10.9	19.1	10.6	24.0	24.2	24.4	30.3	30.3	35.7	36.5	36.9	40.6	41.0	43.4	44.4	44.9	45.0	45.7	59.0	59.8		
	20.1	25.2	10.1	21.5	21.3	27.5	33.1	23.0	26.1	22.9	39.9	23.3	28.3	35.6	20.2	28.8	30.4	14.8	28.2	29.2		
REPLICATIONS																						
2131	10	0	0	0	10	0	0	10	0	5	0	40	0	0	10	0	10	30	45	10	9.0	13.6
2132	0	0	0	0	0	0	0	10	0	10	0	30	5	0	20	10	5	30	10	5	6.8	9.6
1115	35	30	30	60	40	40	60	45	80	75	20	70	70	100	60	70	80	50	90	80	59.3	22.2
1214	50	90	60	90	50	100	100	90	100	90	100	100	100	100	70	95	99	90	100	100	88.7	17.0

Table H-2. Data - Decision 2

(page 1 of 2 pages)

CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MEAN	ST DEV
1111	0	40	15	40	16	3	0	20	37	35	40	30	75	15	1	40	40	60	40	60	30.0	21.5
1112	0	30	0	10	20	0	0	70	10	35	20	50	25	15	2	55	40	80	60	40	28.1	24.9
1113	0	20	85	10	10	0	20	80	30	25	30	30	10	20	80	80	40	80	60	40	37.5	29.3
1121	0	0	0	10	20	90	0	5	49	20	60	30	35	95	95	30	40	80	40	80	38.9	33.8
1122	0	20	10	0	20	30	20	70	30	40	10	50	75	30	55	55	20	6	60	60	33.0	23.6
1123	0	30	75	40	10	15	50	50	15	65	60	40	0	95	5	55	40	50	70	100	43.3	29.7
1131	10	30	0	40	10	50	40	20	39	65	30	50	0	90	2	20	25	30	70	90	35.5	27.2
1132	0	0	40	50	10	30	40	50	11	85	40	60	50	90	35	65	70	70	50	100	47.3	28.4
1133	50	20	40	80	40	25	70	40	8	55	40	40	95	45	55	60	80	60	80	100	54.1	24.4
1141	0	10	0	0	10	20	30	40	40	5	10	50	0	15	80	30	80	60	70	90	32.0	30.2
1142	0	10	0	0	30	15	80	70	38	55	20	30	10	30	35	55	20	60	80	100	36.9	29.7
1143	0	50	45	20	20	15	30	70	20	45	70	60	75	40	75	40	50	80	70	90	48.3	25.2
1151	0	30	0	40	10	40	0	10	70	45	30	60	17	20	5	40	50	80	30	90	33.3	26.8
1152	10	20	30	20	20	10	40	20	20	55	50	30	10	55	60	55	50	60	70	90	39.8	24.3
1153	0	0	60	0	0	5	10	0	35	10	40	20	20	15	60	55	70	10	60	0	23.5	25.0
1161	100	50	25	100	100	100	20	10	98	65	30	90	90	99	1	75	90	90	90	100	68.6	35.2
1162	40	0	15	80	70	2	0	70	91	70	20	70	90	15	15	30	40	70	70	90	47.4	32.9
1163	20	50	30	80	80	5	30	70	10	45	60	40	50	75	50	50	90	60	80	90	50.8	24.1
1211	0	0	0	0	0	2	0	20	70	15	20	30	25	15	1	30	10	50	30	60	18.9	21.2
1212	0	0	0	0	20	5	30	0	14	0	10	20	0	15	10	70	10	70	40	90	20.2	26.9
1213	0	0	10	0	20	2	20	10	35	15	30	30	0	15	75	40	20	70	70	90	25.1	24.6
1221	0	0	10	0	20	6	20	10	90	60	10	20	0	15	1	10	30	70	40	40	22.6	25.5
1222	0	0	0	0	70	25	20	10	20	20	50	10	0	15	25	25	20	30	40	60	20.0	16.9
1223	0	10	25	0	10	10	30	10	20	20	50	30	75	45	75	55	40	70	50	90	35.8	27.1
1231	0	10	0	0	10	30	0	0	85	30	20	30	15	70	5	20	70	25	60	90	28.5	30.0
1232	0	30	0	0	20	30	40	0	20	20	50	30	0	15	55	45	70	70	30	90	30.8	26.3
1233	0	40	20	0	40	10	40	20	30	20	50	40	0	20	50	55	80	50	40	90	34.8	24.6
1241	0	20	0	0	10	5	0	0	88	35	20	30	0	20	5	20	20	60	40	80	22.6	26.5
1242	0	10	0	0	0	20	0	10	29	45	30	20	0	15	85	40	40	50	30	80	25.2	25.7
1243	0	40	25	0	10	15	30	10	30	30	40	30	10	25	80	50	60	60	50	90	34.3	24.9
1251	20	0	0	0	40	10	30	0	60	10	20	20	25	20	1	30	20	70	30	50	22.8	20.2
1252	0	30	0	0	40	20	50	0	29	75	40	40	0	20	50	70	80	60	80	100	39.2	31.2
1253	10	60	40	100	10	5	60	80	75	45	40	60	0	90	99	40	80	50	60	90	54.7	31.2
1261	100	30	10	100	90	90	30	30	90	85	20	80	0	15	0	55	90	80	70	100	58.3	36.9
1262	100	50	50	100	100	100	90	100	30	70	50	70	90	20	99	40	90	90	80	100	75.9	26.6
1263	100	100	60	100	100	100	60	100	30	95	40	90	95	95	100	55	90	95	60	90	82.8	22.7
1311	0	0	0	0	0	0	0	50	9	0	20	10	0	10	1	40	10	30	30	0	10.5	15.4
1312	0	0	0	0	0	0	0	0	10	10	20	10	0	15	1	30	20	40	30	0	9.3	12.6
1313	0	0	10	0	0	5	0	0	40	0	20	10	0	15	1	30	30	30	40	0	11.5	14.7
1321	0	0	0	0	0	80	0	0	96	15	20	10	0	10	1	10	10	40	60	0	17.6	28.7
1322	0	0	0	0	0	0	0	0	17	0	20	10	25	15	1	30	10	30	40	0	9.9	12.9
1323	0	0	10	0	0	1	20	0	20	10	20	10	0	20	1	45	10	30	50	0	12.3	15.2
1331	0	0	0	0	0	70	0	0	94	0	30	10	25	15	0	10	10	20	30	0	15.7	25.3
1332	0	0	0	0	20	3	0	0	10	0	50	10	25	15	0	20	20	25	20	0	10.9	13.4
1333	0	0	0	0	0	0	30	0	10	10	50	10	75	15	35	20	60	30	40	0	19.3	22.8
1341	0	0	0	0	0	90	0	0	79	5	30	10	0	15	1	10	20	50	30	0	17.0	26.9
1342	0	0	0	0	0	0	0	0	25	0	40	10	0	15	5	30	10	40	40	0	10.8	15.3
1343	0	0	15	0	0	3	0	0	20	25	10	10	0	15	1	30	20	20	40	0	10.4	12.1
1351	0	0	0	0	10	90	0	0	78	10	10	10	0	15	5	15	0	40	30	0	15.6	25.9
1352	0	0	0	0	0	0	0	0	5	10	20	10	50	10	5	20	20	15	50	0	10.8	15.3
1353	0	0	10	0	20	3	40	10	32	50	50	50	90	20	90	40	90	15	40	90	37.0	32.1
1361	20	10	0	80	50	5	0	50	90	30	10	60	75	20	1	30	20	50	50	0	32.5	28.8
1362	100	20	50	90	100	100	100	100	20	90	20	70	75	15	100	60	80	80	80	100	72.5	31.1
1363	100	50	75	100	100	100	70	100	40	85	50	70	93	90	99	70	80	99	80	90	82.0	18.9
2111	0	10	0	20	40	15	30	70	10	5	40	40	75	15	35	70	80	70	90	80	39.8	30.5
2112	0	10	0	0	10	20	0	50	20	25	20	40	75	25	25	80	40	50	70	90	32.5	28.4
2113	0	90	30	50	20	5	90	50	19	45	40	40	87	25	80	70	80	80	60	80	52.0	29.2
2121	0	20	10	50	40	30	30	50	48	25	40	30	90	15	5	50	80	80	60	80	41.6	26.4
2122	0	0	25	10	30	25	30	70	10	40	70	60	75	85	50	65	30	60	80	60	43.8	27.2
2123	0	10	20	0	0	3	70	0	2	10	40	40	0	40	5	20	10	40	40	0	17.5	20.4

Table H-2. Data - Decision 2
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CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MEAN	ST DEV
2131	0	100	10	80	100	25	20	70	5	75	40	30	14	85	65	25	80	70	70	90	52.7	33.7
2132	0	0	50	0	0	5	20	0	15	20	20	10	25	25	10	20	70	30	40	0	16.0	14.7
2133	0	20	25	0	0	10	0	0	15	0	60	40	0	60	40	30	60	20	70	0	22.5	24.5
2141	0	0	0	0	0	85	0	20	20	10	10	10	0	20	1	10	10	10	40	0	12.3	20.0
2142	0	0	0	0	0	2	0	0	20	10	50	10	10	15	1	30	30	15	20	0	10.6	13.7
2143	0	0	40	0	0	10	50	10	6	10	30	30	0	50	0	20	10	30	40	0	16.8	17.9
2151	0	0	0	0	0	80	30	0	49	0	20	10	10	35	10	10	30	60	70	0	20.7	25.7
2152	0	0	0	0	0	30	0	0	28	15	20	20	0	10	5	30	70	40	30	0	14.9	18.8
2153	0	0	40	0	0	15	90	0	1	10	30	30	25	85	40	40	80	45	50	0	29.0	29.8
2161	10	0	0	80	90	70	0	50	65	5	40	50	50	20	5	20	10	70	70	0	35.3	31.4
2162	50	0	0	80	40	30	0	50	20	10	20	60	10	20	60	55	40	50	70	90	37.8	27.3
2163	20	0	20	80	50	30	50	50	12	40	70	60	90	80	75	30	50	50	80	60	49.8	25.3
2211	0	20	0	0	40	15	0	20	35	55	30	50	0	5	85	75	50	50	60	60	32.5	27.4
2212	0	0	0	0	20	10	50	40	8	10	20	20	80	10	40	60	20	60	50	80	28.9	26.6
2213	0	0	40	20	20	40	50	50	20	50	50	60	75	15	10	40	60	50	70	60	39.0	22.6
2221	0	30	0	0	20	40	30	10	35	40	20	40	75	60	80	30	20	70	40	90	36.5	26.8
2222	20	0	0	0	40	20	10	0	35	45	40	30	75	20	15	70	20	70	70	90	33.5	28.3
2223	10	30	75	10	30	20	70	80	25	85	70	60	90	95	99	75	40	70	90	100	61.2	30.7
2231	0	30	0	20	30	80	50	0	47	25	40	40	10	90	5	40	90	80	50	90	40.8	31.4
2232	0	0	0	50	20	15	90	70	30	30	30	30	25	95	60	65	40	70	70	90	44.0	30.8
2233	0	30	95	80	30	10	90	50	21	85	70	50	85	99	99	55	90	90	70	90	64.4	31.6
2241	0	0	0	20	30	15	100	50	55	40	40	50	90	20	65	55	70	80	80	90	47.5	31.8
2242	0	50	0	0	40	30	70	70	10	30	60	50	25	85	80	40	40	80	70	90	46.0	29.4
2243	0	20	75	20	40	20	100	100	20	75	30	60	80	99	30	70	80	85	70	90	58.2	32.3
2251	0	30	25	100	40	40	50	80	65	15	40	60	85	90	90	55	80	70	60	90	58.3	28.0
2252	50	30	25	60	20	50	90	70	5	40	60	50	75	20	60	55	50	30	70	40	47.5	21.4
2253	0	70	90	60	30	70	100	70	50	35	60	70	75	90	95	45	80	80	80	90	67.0	24.9
2261	100	100	40	100	100	0	50	80	20	95	70	80	75	85	99	55	90	70	90	100	74.9	28.7
2262	100	90	10	100	100	98	100	100	10	100	60	80	90	95	95	90	90	80	100	100	83.9	27.1
2263	100	100	100	100	100	100	100	100	23	100	70	90	90	90	100	80	100	90	60	100	89.6	19.3
2311	0	0	0	0	0	90	0	0	20	10	30	10	0	40	2	25	10	10	50	0	14.8	23.1
2312	0	0	0	0	0	2	0	0	20	22	30	10	15	15	5	30	40	50	30	0	13.4	15.6
2313	0	20	20	0	0	5	10	0	12	10	20	10	50	10	20	30	20	4	70	0	15.5	17.8
2321	0	0	0	0	0	3	0	0	41	10	20	10	0	15	5	40	10	30	60	0	12.2	17.4
2322	0	0	0	0	0	15	0	0	18	10	30	10	0	25	10	10	10	20	70	0	11.4	16.7
2323	0	0	60	0	50	20	30	20	3	25	30	20	85	50	25	55	40	70	50	90	36.1	27.2
2331	0	0	0	0	0	5	0	0	65	5	10	10	0	20	5	10	10	50	60	0	12.5	20.6
2332	0	0	0	0	40	15	20	0	90	25	50	20	15	25	80	45	50	70	60	90	32.3	28.0
2333	0	20	80	0	80	5	30	2	50	25	50	40	25	90	95	65	70	60	40	90	46.4	32.7
2341	0	20	0	0	30	15	30	20	25	30	10	50	40	70	5	30	50	60	60	90	31.8	25.1
2342	0	0	0	0	10	40	20	20	35	25	40	50	90	40	80	70	20	70	40	80	36.5	29.1
2343	0	20	75	0	30	70	30	10	50	20	40	40	50	20	75	70	70	60	70	90	44.5	27.4
2351	0	60	0	0	20	20	20	70	45	35	30	10	20	55	95	60	90	70	60	90	42.7	31.1
2352	0	0	0	0	60	30	10	0	18	50	40	30	23	55	95	55	40	70	40	90	35.3	29.7
2353	0	0	85	0	40	50	40	20	17	30	50	60	85	50	95	55	100	70	60	90	49.8	31.9
2361	100	50	20	100	100	95	70	100	80	75	30	60	90	80	1	30	90	90	90	100	72.5	30.6
2362	100	20	35	100	90	100	80	100	25	75	50	70	95	40	99	65	90	70	80	90	73.7	26.4
2363	100	40	75	100	100	100	100	100	30	100	70	80	90	85	99	70	80	90	90	100	84.9	20.2
	14.3	19.1	20.2	25.7	29.4	30.9	32.3	32.7	34.0	34.7	36.0	37.7	39.0	40.9	41.5	43.8	47.6	56.3	56.9	59.1		
	32.0	25.9	27.5	37.6	32.0	33.0	32.1	34.8	25.2	28.0	17.1	22.6	36.7	31.5	38.1	19.9	29.0	23.4	18.1	41.0		
REPLICATIONS																						
1151	0	10	0	20	10	20	30	10	90	35	20	30	10	25	1	30	90	30	40	90	27.0	24.9
1312	0	0	0	0	0	0	0	0	13	0	20	10	0	10	5	10	10	30	30	0	6.9	9.8
1322	0	0	0	0	0	0	0	0	10	25	20	10	0	15	1	40	20	10	20	0	8.5	11.4
2261	100	100	25	100	100	3	100	100	87	100	40	80	90	85	99	80	90	90	90	100	82.9	27.5

Table H-3. Data - Decision 3

CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MEAN	ST DEV
1111	10	25	11	20	5	20	40	40	50	20	70	90	10	70	60	65	20	20	75	70	39.5	26.8
1112	5	10	10	20	10	2	30	20	25	20	40	20	20	35	40	80	0	30	50	60	26.3	20.3
1121	30	40	10	15	15	90	40	60	75	40	70	75	10	70	80	75	20	85	75	80	52.8	28.2
1122	10	15	10	10	15	65	30	20	50	20	40	40	50	40	60	85	0	75	75	50	38.0	25.3
1211	25	25	20	50	20	40	45	40	5	35	50	75	40	40	80	55	95	10	75	80	45.3	25.1
1212	5	15	10	20	25	10	40	20	25	20	20	50	10	50	60	60	80	10	50	70	32.5	22.9
1221	55	25	20	35	30	75	55	50	75	45	70	100	45	70	80	70	100	75	75	80	61.5	23.1
1222	5	10	10	30	35	50	50	20	50	25	50	20	50	40	60	80	80	90	75	70	45.0	25.5
1311	40	25	40	50	30	25	60	50	50	30	40	75	53	70	60	80	25	85	75	80	52.1	20.2
1312	40	15	10	30	5	20	50	40	25	25	30	40	20	40	70	55	0	50	75	60	35.0	20.8
1321	55	25	33	40	25	80	50	40	50	30	50	90	40	75	80	85	100	75	75	60	57.9	23.1
1322	20	15	0	25	50	30	50	40	50	45	50	40	95	50	70	75	80	75	50	50	48.0	23.4
1411	30	30	0	30	50	50	50	30	25	35	30	50	45	60	60	80	85	30	75	70	45.8	21.5
1412	10	15	10	20	5	85	50	20	5	35	50	20	30	40	40	80	85	70	50	70	39.5	27.1
1421	40	25	10	35	30	70	50	20	50	40	60	50	60	60	80	80	95	90	75	80	55.0	24.2
1422	5	20	10	25	20	85	40	40	50	30	50	25	21	40	40	85	80	100	75	80	46.0	28.5
1511	25	15	10	20	60	30	40	50	5	30	70	90	50	75	80	75	25	20	95	60	46.3	28.0
1512	10	10	0	20	15	10	25	40	25	20	50	50	40	50	60	65	85	50	50	50	36.3	22.4
1521	30	30	20	40	45	75	70	30	50	35	60	100	50	40	60	80	100	75	75	70	56.8	23.4
1522	20	20	5	30	40	70	45	30	50	25	60	50	59	70	80	60	90	75	75	80	51.7	24.1
1611	30	25	0	35	45	50	30	30	5	40	50	40	65	95	80	80	50	50	90	60	47.5	25.6
1612	25	25	10	35	25	40	60	70	5	20	50	20	60	80	80	75	50	50	75	80	46.8	25.1
1621	65	45	55	40	35	80	70	70	75	65	50	50	80	90	100	80	80	100	90	90	70.5	19.5
1622	10	10	0	35	80	80	50	50	10	25	50	30	95	90	80	85	100	100	75	90	57.3	34.2
2111	20	50	90	20	65	40	30	90	75	65	80	100	65	80	80	75	100	100	95	100	71.0	26.5
2112	5	15	0	20	10	32	40	90	25	80	60	100	80	80	80	80	85	100	75	100	58.0	35.4
2121	30	60	40	25	75	40	70	80	95	95	70	100	95	85	80	90	100	100	95	100	76.3	24.8
2122	30	40	55	30	85	85	45	60	50	65	80	75	90	75	80	85	95	90	75	90	69.4	21.3
2211	30	40	65	75	45	35	60	80	95	65	70	50	95	75	100	85	90	100	90	100	72.3	22.9
2212	20	25	45	40	55	45	45	80	75	65	50	100	40	75	70	70	85	100	90	100	63.8	24.6
2221	65	60	90	80	90	80	70	90	95	85	80	100	99	80	100	95	100	100	90	100	87.4	12.2
2222	30	25	40	50	45	85	50	70	50	75	70	20	99	80	100	90	100	100	90	90	67.9	27.0
2311	45	45	75	80	45	35	85	80	95	95	60	100	60	85	80	85	100	100	99	100	77.4	21.6
2312	15	35	33	35	40	15	50	50	75	95	70	100	40	85	80	85	95	90	75	90	62.6	28.0
2321	55	60	85	75	60	100	95	80	95	90	80	100	100	85	100	80	100	100	99	100	86.9	14.9
2322	20	40	50	40	35	75	65	70	75	65	80	40	80	85	100	90	100	100	75	100	69.3	24.5
2411	50	35	80	50	30	30	65	80	75	90	50	50	60	70	80	85	100	100	95	100	68.8	23.4
2412	40	20	40	60	50	20	75	60	75	75	40	50	90	75	80	50	100	100	75	100	63.8	24.8
2421	60	55	60	75	65	40	80	20	95	90	80	90	73	85	100	95	90	100	90	100	77.1	21.6
2422	10	25	50	50	30	70	60	70	50	85	70	50	90	75	50	85	85	100	75	100	64.4	24.8
2511	50	60	80	45	25	35	60	70	75	90	60	100	70	85	100	85	100	30	90	100	70.5	24.2
2512	25	40	45	40	75	30	50	80	75	65	50	35	90	80	80	80	85	100	90	100	65.8	24.1
2521	65	50	65	75	25	95	95	60	95	85	50	85	79	90	100	90	100	100	90	100	79.7	20.9
2522	50	45	50	45	65	80	55	70	50	60	80	40	80	85	90	85	80	100	75	80	68.3	17.6
2611	70	60	95	50	65	45	90	80	75	80	60	35	98	90	100	85	95	100	90	100	78.1	19.9
2612	60	65	40	40	25	65	30	70	50	95	70	40	80	85	100	80	85	100	95	100	68.3	24.8
2621	60	65	80	75	95	100	85	80	95	95	60	90	90	90	100	70	100	100	99	100	86.4	13.9
2622	35	60	75	30	50	90	60	50	75	85	70	75	100	90	100	90	100	100	90	100	76.3	22.3
	31.9	33.1	36.3	39.9	40.9	51.3	54.8	54.8	55.6	56.0	58.3	62.8	63.6	71.0	78.5	78.8	79.1	79.2	79.7	84.2		
	19.2	17.1	29.9	18.8	23.4	27.6	17.6	22.6	28.5	27.3	14.8	28.7	27.6	17.7	17.5	10.3	30.1	28.6	13.4	16.6		
REPLICATIONS																						
1221	35	35	25	40	15	90	55	50	25	30	40	75	50	50	90	80	85	75	90	70	55.3	24.7
1511	20	40	30	3	65	20	50	50	5	25	60	75	40	75	80	55	50	20	75	60	44.9	23.9
1612	15	30	0	40	65	20	40	50	25	30	30	25	100	85	80	75	85	30	75	80	49.0	28.9
2222	35	40	60	50	85	95	50	80	75	75	80	100	94	80	100	90	95	100	95	100	78.9	21.1

Table H-4. Data - Decision 5

CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	MEAN	ST DEV
111	0	20	0	0	0	5	0	10	20	1	0	10	30	10	13	40	20	25	50	20	80	16.9	20.2
112	0	10	10	0	0	15	20	20	25	8	0	60	50	10	40	60	60	60	70	80	80	32.3	28.6
121	0	1	0	0	0	5	0	10	2	1	0	0	30	10	12	40	10	40	50	20	60	17.9	18.8
122	0	20	10	0	0	15	20	20	20	3	50	10	40	10	14	60	60	25	50	70	75	27.7	24.1
131	0	1	0	0	0	5	0	10	2	2	0	0	0	10	16	10	10	0	20	10	50	7.0	11.6
132	0	1	10	0	0	15	20	20	15	2	0	10	10	10	14	50	50	40	60	40	80	21.3	23.0
211	10	20	70	70	90	40	70	50	80	90	50	90	100	90	90	90	80	85	60	70	90	68.3	25.0
212	20	30	70	70	80	80	80	60	99	80	90	100	100	90	90	90	90	100	80	90	98	80.3	21.4
221	0	20	20	30	5	40	40	50	20	70	50	30	80	60	75	40	50	45	45	70	97	45.6	25.9
222	10	20	20	50	70	70	40	60	75	60	80	70	50	80	90	80	80	100	65	85	87	63.9	24.5
231	0	1	20	20	30	10	30	50	35	70	50	20	30	80	60	40	60	40	25	40	90	38.1	24.2
232	0	40	30	20	20	50	50	70	50	60	80	80	30	80	80	50	50	80	70	80	80	53.8	24.2
	3.3	16.2	21.7	21.7	24.6	29.2	30.8	34.2	36.9	37.3	37.5	40.0	45.8	46.7	49.5	50.0	51.7	53.3	53.8	56.3	80.6		
	6.5	13.4	24.4	27.6	35.0	26.4	26.4	20.7	32.0	36.8	35.7	37.4	32.3	38.5	34.5	20.9	26.6	31.9	17.9	28.5	14.1		
REPLICATIONS																							
111	0	20	0	0	0	5	0	10	5	5	0	20	0	10	17	50	30	20	50	30	98	17.6	29.1
121	0	1	0	0	0	5	0	10	2	1	0	0	0	10	15	40	10	0	20	15	40	8.0	12.3
132	0	10	10	0	0	15	20	50	10	25	0	0	30	10	15	40	40	20	70	50	80	23.6	23.5
212	20	50	70	40	90	80	80	50	99	80	90	100	100	90	90	90	90	95	85	90	98	79.9	21.8

Table H-5. Data - Decision 6

CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	MEAN	ST DEV
111	0	15	40	10	20	5	30	50	25	45	30	40	45	30	49	75	50	50	60	50	30	35.7	18.9
112	30	15	30	30	20	30	60	90	40	75	75	55	76	80	60	100	70	75	70	80	70	58.6	24.6
121	0	0	20	30	20	5	15	50	10	35	25	30	45	20	40	50	40	40	50	50	50	29.8	17.2
122	20	15	20	50	20	40	60	30	30	50	50	60	40	60	70	50	80	75	60	75	80	49.3	20.9
131	0	0	30	0	20	5	10	0	10	30	30	30	5	10	30	50	40	20	40	25	50	20.7	16.5
132	0	5	30	10	20	30	50	50	20	60	60	60	79	70	60	50	80	30	60	90	70	46.9	26.0
211	75	70	30	40	50	50	25	70	85	65	70	90	87	80	80	50	70	95	95	85	90	69.1	20.9
212	80	75	40	90	50	75	80	70	90	85	100	90	99	90	99	100	95	100	90	100	100	85.6	16.5
221	15	30	30	20	50	40	35	10	85	50	50	60	75	70	70	100	60	90	80	75	100	56.9	27.2
222	40	40	30	80	50	70	60	60	75	65	80	80	50	90	80	75	90	90	80	100	90	70.2	19.3
231	0	50	30	20	50	25	30	30	50	50	50	70	98	70	60	25	65	80	80	65	90	51.8	25.3
232	75	75	30	30	50	50	70	30	60	65	80	70	45	80	70	50	80	90	70	75	90	61.7	19.6
	27.9	29.2	30.0	34.2	35.0	35.4	43.8	45.0	48.3	56.3	58.3	61.3	62.0	62.5	64.0	64.6	68.3	69.6	69.6	68.3	75.8		
	32.2	25.7	6.0	27.5	15.7	23.7	22.6	26.1	30.1	16.0	23.4	20.5	28.1	27.3	18.7	24.9	18.1	27.4	16.3	22.1	22.3		
REPLICATIONS																							
111	25	20	40	20	20	5	20	30	20	50	30	40	65	25	49	25	60	20	70	75	40	35.7	19.3
121	40	5	20	20	20	5	20	50	10	35	30	30	30	20	60	25	50	30	50	45	60	31.2	16.6
132	0	0	20	10	20	30	40	50	30	60	60	60	60	60	60	50	60	75	40	75	70	44.3	23.5
212	60	25	40	70	50	75	80	90	90	85	100	90	98	95	99	50	95	80	90	100	90	78.7	21.6

Table H-6. Data - Decision 7

CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MEAN	ST DEV
111	20	10	50	40	60	40	50	50	20	40	60	60	40	20	70	10	40	70	50	75	43.8	19.7
112	25	15	40	20	20	0	30	40	0	30	40	20	60	30	40	10	40	45	50	30	29.3	15.8
113	10	5	20	0	20	0	10	10	0	30	10	5	50	20	5	10	30	30	60	15	17.0	16.3
121	10	10	50	40	20	60	30	60	20	20	80	50	30	30	80	50	30	70	50	50	42.0	21.4
122	15	10	30	20	20	0	20	10	0	20	30	20	30	30	40	10	30	45	50	30	23.0	13.5
123	15	5	0	0	15	0	10	10	0	10	5	5	60	10	15	10	20	20	50	15	13.8	15.5
131	5	10	20	20	30	0	40	50	90	30	75	50	0	60	40	10	50	60	10	55	35.3	25.9
132	5	10	30	0	40	0	30	30	0	10	40	5	20	20	10	50	20	40	25	30	20.8	15.3
133	1	0	0	0	5	0	10	10	0	10	5	5	30	10	5	10	40	10	10	15	8.8	10.2
211	45	75	90	100	95	100	60	100	100	90	85	80	80	95	95	90	90	100	95	90	87.8	14.3
212	35	65	50	80	60	80	70	70	90	70	45	80	80	95	85	80	80	75	90	85	73.3	15.7
213	60	75	50	80	40	60	70	50	100	60	45	80	100	95	60	90	70	40	95	95	70.8	20.4
221	20	60	50	40	70	100	50	50	80	90	90	80	60	80	90	90	90	85	90	85	72.5	21.4
222	20	50	30	60	40	80	60	70	60	60	50	60	40	60	70	90	70	70	90	80	60.5	18.5
223	15	50	20	40	30	60	40	30	90	50	20	80	60	20	40	90	50	45	90	75	49.8	24.7
231	35	35	20	40	60	40	70	60	40	70	80	50	0	50	70	90	50	50	40	85	51.8	22.1
232	25	35	10	40	25	40	50	20	30	60	50	50	40	80	50	50	80	70	50	80	46.8	20.1
233	10	25	0	20	15	20	30	30	30	40	10	50	60	80	30	80	60	35	40	80	37.3	24.1
	20.6	30.3	31.1	35.6	36.9	37.8	40.6	41.7	41.7	43.9	45.6	46.1	46.7	49.2	49.7	51.1	52.2	53.3	57.5	59.4		
	15.2	25.9	23.2	29.6	23.6	36.9	20.7	25.3	40.0	26.2	28.5	29.0	26.6	31.6	29.4	36.4	23.2	23.3	28.2	29.2		
REPLICATIONS																						
111	10	10	60	40	65	60	40	50	20	20	70	60	49	30	75	50	60	70	50	65	47.7	20.2
121	10	20	50	20	20	40	40	60	0	30	50	50	30	75	70	10	30	60	60	70	39.8	22.3
132	5	10	0	0	10	0	20	20	0	20	20	5	10	10	30	10	20	45	10	30	13.8	11.9
212	40	45	70	100	50	80	70	70	90	70	65	80	80	95	80	90	80	80	95	85	75.8	16.3

Table H-7. Data - Decision 8

CELL ID	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MEAN	ST DEV
111	20	40	45	60	95	0	55	25	75	75	80	50	50	20	65	50	85	80	60	100	56.5	26.6
112	10	20	25	30	35	0	50	20	50	45	55	40	50	20	40	50	55	75	70	100	42.0	23.6
113	15	0	15	20	25	0	20	40	25	30	20	40	40	20	30	60	55	75	40	80	32.5	21.8
121	25	20	60	40	15	40	30	20	65	60	75	60	50	20	70	50	80	70	80	60	49.5	21.8
122	10	0	15	20	10	0	35	20	35	50	60	40	50	20	30	50	50	50	70	80	34.8	22.7
123	10	0	15	20	5	20	50	40	15	25	28	20	40	10	30	50	40	25	20	50	25.6	15.1
131	20	20	10	50	5	20	15	30	65	66	78	35	50	10	60	50	60	40	80	60	41.2	23.8
132	5	0	25	20	10	0	15	10	30	40	45	40	40	20	75	50	40	25	20	40	27.5	19.0
133	10	0	20	10	10	0	10	40	10	25	1	25	40	100	25	50	40	35	30	20	25.0	23.0
211	50	100	90	80	95	100	75	60	100	80	100	90	80	100	95	80	85	95	100	100	87.8	14.2
212	30	100	65	60	80	100	55	75	70	65	75	80	80	90	85	80	85	95	95	100	78.3	17.6
213	30	100	55	50	90	80	60	95	50	45	30	90	50	100	80	80	85	95	90	100	72.8	23.9
221	40	60	25	40	80	100	70	55	85	7	90	80	60	100	85	80	80	95	90	100	71.1	26.3
222	40	60	55	50	50	60	60	34	60	70	50	60	70	90	75	80	80	90	90	80	65.2	16.5
223	25	40	25	30	70	100	60	90	40	60	25	90	70	100	80	80	80	80	90	80	65.8	26.0
231	40	60	70	40	25	20	60	35	70	70	80	70	80	90	85	80	70	80	100	80	65.3	22.2
232	25	60	35	50	30	40	50	45	55	75	95	40	40	90	70	80	55	70	80	60	54.8	18.1
233	25	20	65	50	10	100	30	85	35	60	20	50	70	90	65	70	55	80	80	60	56.0	25.7
	27.9	38.9	39.7	40.0	41.1	43.3	44.4	45.5	51.9	52.7	53.2	55.6	56.1	60.6	63.6	65.0	65.6	69.7	71.4	75.0		
	12.8	36.0	23.8	18.1	34.3	42.4	20.1	25.9	24.3	20.7	28.3	22.9	15.0	39.9	22.6	14.7	17.2	24.2	26.6	23.8		
REPLICATIONS																						
111	25	40	25	30	70	100	60	90	40	60	25	90	70	100	80	80	80	80	90	80	65.8	26.0
121	40	60	55	50	50	60	60	34	60	70	50	60	70	90	75	80	80	90	90	80	65.2	16.5
132	10	0	15	20	5	20	50	40	15	25	28	20	40	10	30	50	40	25	20	50	25.6	15.1
212	40	60	25	40	80	100	70	55	85	7	90	80	60	100	65	80	80	95	90	100	71.1	26.3

Table H-8. Data - Decision 4

	ATTACK COUNT	DEFEND COUNT	DELAY COUNT	WITHDRAW COUNT	FORCE RATIO	POSTURE	LOCATION
111	0	10	51	20	1:3	DELAY	REAR
112	1	37	32	11	1:3	DEFEND	REAR
113	5	59	16	1	1:3	ATTACK	REAR
121	1	42	36	2	1:3	DELAY	REACHED
122	0	72	8	1	1:3	DEFEND	REACHED
123	16	61	3	1	1:3	ATTACK	REACHED
131	1	56	22	2	1:3	DELAY	FORWARD
132	7	68	6	0	1:3	DEFEND	FORWARD
133	29	51	5	1	1:3	ATTACK	FORWARD
211	3	23	97	8	1:1	DELAY	REAR
212	1	47	25	8	1:1	DEFEND	REAR
213	17	53	9	2	1:1	ATTACK	REAR
221	2	46	33	0	1:1	DELAY	REACHED
222	4	70	7	0	1:1	DEFEND	REACHED
223	28	49	4	0	1:1	ATTACK	REACHED
231	10	51	19	1	1:1	DELAY	FORWARD
232	22	52	6	1	1:1	DEFEND	FORWARD
233	43	36	2	0	1:1	ATTACK	FORWARD
311	18	27	31	5	3:1	DELAY	REAR
312	17	38	17	9	3:1	DEFEND	REAR
313	52	22	3	4	3:1	ATTACK	REAR
321	27	39	15	0	3:1	DELAY	REACHED
322	28	53	0	0	3:1	DEFEND	REACHED
323	67	13	1	0	3:1	ATTACK	REACHED
331	58	18	4	1	3:1	DELAY	FORWARD
332	70	9	2	0	3:1	DEFEND	FORWARD
333	81	0	0	0	3:1	ATTACK	FORWARD

APPENDIX I

STATISTICAL ANALYSIS

This appendix contains data supporting the statistical analysis documented in Chapter 6 of the main report. The first two tables, repeated for ease of reference from Chapter 4 of the main report, list the factors (i.e., perception data base variables) for the experiments, and the levels considered for the factors.

Table I-1. Decision Factors

Symbol	Interpretation
A	Has reserve corps
B	Corps engagement status
C	Corps force ratio
D	Location of objective of corps/posture of corps
E	Echelon to which corps assigned/has reserve corps
F	Echelon to which corps assigned
G	Ratio of corps artillery battalions to divisions
M	Location of objective of corps
N	Posture of parent army
P	Division engagement status
R	Division force ratio
S	Echelon to which division assigned

Table I-2. Levels of Decision Factors

Factor	Level 1	2	3	4	5	6
A	No res	Has res				
B	Not eng	Engaged				
C	1:3	1:1	3:1			
D	Rear/ Withdr	Reached/ Delay	Reached/ Defend	Fwd/ Delay	Fwd/ Defend	Fwd/ Attack
E	Reserv	Online/ Yes	Online/ No			
F	Reserv	Online				
G	1.00	0.25				
M	Rear	Reached	Forward			
N	Delay	Defend	Attack			
P	No	Yes				
R	1:3	1:1	3:1			
S	First	Second	Third			

Table I-3. Model Measures

Decision	Perspective	Number of cells (c)	Number of params (p)	Parsimony ratio (p/c)	Adequacy mallow (C_p)	% Variation (R^2) explained by		
						Regression equation (r)	Cell means (m)	Ratio (r/m)
1	Blue	72	10	14	-12	44	45	0.96
2	Blue	108	27	25	17	36	39	0.94
3	Blue	48	7	15	20	29	30	0.96
5	Blue	12	5	42	0.09	50	50	0.99
6	Blue	12	4	33	2.2	40	41	0.96
7	Blue	18	6	33	0.13	58	59	0.99
8	Blue	18	4	22	1.1	41	43	0.96

Table I-4. Cell Means - Decision 1

A	B	C	D=1	D=2	D=3	D=4	D=5	D=6
1	1	1	44	47	56	54	64	82
		2	27	33	32	43	47	76
		3	14	18	24	21	22	45
	2	1	54	47	67	61	64	82
		2	36	41	44	51	48	82
		3	16	20	32	23	33	55
2	1	1	28	32	36	36	33	64
		2	17	19	22	20	33	56
		3	7	6	13	11	14	36
	2	1	25	30	36	37	39	72
		2	13	20	20	35	32	60
		3	8	8	12	12	20	29

Table I-5. Marginal Means - Decision 1

Factors	Levels					
	1	2	3	4	5	6
A	45	28				
B	34	38				
C	50	38	21			
D	25	27	33	34	37	62

Overall = 36.2

Table I-6. ANOVA Table - Decision 1

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Level of significance
A	1	103,598	103,598	65.1	***
B	1	5,413	5,413	12.7	**
C	2	199,277	99,639	82.2	***
D	5	212,999	42,600	34.8	***
AB	1	1,805	1,805	6.2	*
AC	2	4,362	2,181	5.8	**
AD	5	941	188	< 1.0	
BC	2	282	141	< 1.0	
BD	5	697	139	< 1.0	
CD	10	8,432	843	3.0	**
ABC	2	114	57	< 1.0	
ABD	5	1,260	252	1.6	
ACD	10	3,977	398	2.0	*
BCD	10	1,565	157	< 1.0	
ABCD	10	2,732	273	1.5	
T	19	205,476	10,815	92.2	***
AT	19	30219	1,590	13.6	***
BT	19	8,080	425	3.6	***
CT	38	46,048	1,212	10.3	***
DT	95	116,210	1,223	10.4	***
ABT	19	5,495	289	2.5	**
ACT	38	14,233	375	3.2	***
ADT	95	21,219	223	1.9	***
BCT	38	8,552	225	1.9	***
BDT	95	18,367	193	1.6	**
CDT	190	54,006	284	2.4	***
ABCT	38	7,998	210	1.8	**
ABDT	95	15,244	160	1.4	*
ACDT	190	37,207	196	1.7	**
BCDT	190	39,349	207	1.8	***
ABCDT	190	34,892	184	1.6	**
Error	80	9,388	117		

* Significant at the 0.05 level of significance
** Significant at the 0.01 level of significance
*** Significant at the 0.001 level of significance

Table I-7. Comparison of Models - Decision 1

REGRESSION MODEL PREDICTED VALUE AND PRIORITY		CELL MEAN CRITICAL INDEX AND PRIORITY		PRESENT FORCEM PRIORITY	NUMBER CORPS IN RESERVE	ENGAGED	FORCE RATIO FR:EN	POSTURE	LOCATION
1	86.4	1	82.0	1	C	YES	1:3	ATTACK	FORWARD
2	82.5	2	81.9	19	C	NO	1:3	ATTACK	FORWARD
3	76.1	3	81.7	2	C	YES	1:1	ATTACK	FORWARD
4	72.2	4	76.3	20	C	NO	1:1	ATTACK	FORWARD
5	65.2	5	71.8	37	1	YES	1:3	ATTACK	FORWARD
6	61.6	6	66.8	10	C	YES	1:3	DEFEND	REACHED
7	61.3	7	64.4	55	1	NO	1:3	ATTACK	FORWARD
8	59.6	8	64.3	4	C	YES	1:3	DEFEND	FORWARD
9	59.6	10	61.0	7	C	YES	1:3	DELAY	FORWARD
10	59.2	11	59.5	38	1	YES	1:1	ATTACK	FORWARD
11	57.7	13	55.8	28	C	NO	1:3	DEFEND	REACHED
12	55.7	9	63.5	22	C	NO	1:3	DEFEND	FORWARD
13	55.7	16	54.3	25	C	NO	1:3	DELAY	FORWARD
14	55.3	12	56.0	56	1	NO	1:1	ATTACK	FORWARD
15	53.6	21	46.8	13	C	YES	1:3	DELAY	REACHED
16	53.5	14	55.0	3	C	YES	3:1	ATTACK	FORWARD
17	51.4	15	54.3	16	C	YES	1:3	WITHDRAW	REAR
18	49.8	19	47.0	31	C	NO	1:3	DELAY	REACHED
19	49.6	22	45.0	21	C	NO	3:1	ATTACK	FORWARD
20	49.3	17	50.9	8	C	YES	1:1	DELAY	FORWARD
21	49.3	18	47.8	5	C	YES	1:1	DEFEND	FORWARD
22	47.5	23	44.5	34	C	NO	1:3	WITHDRAW	REAR
23	45.4	20	46.8	23	C	NO	1:1	DEFEND	FORWARD
24	45.4	25	43.0	26	C	NO	1:1	DELAY	FORWARD
25	45.2	24	44.2	11	C	YES	1:1	DEFEND	REACHED
26	41.3	41	31.5	29	C	NO	1:1	DEFEND	REACHED
27	40.8	44	29.3	39	1	YES	3:1	ATTACK	FORWARD
28	40.4	32	35.8	46	1	YES	1:3	DEFEND	REACHED
29	38.3	27	39.0	40	1	YES	1:3	DEFEND	FORWARD
30	38.3	28	37.3	43	1	YES	1:3	DELAY	FORWARD
31	37.2	26	40.8	14	C	YES	1:1	DELAY	REACHED
32	36.9	31	36.0	57	1	NO	3:1	ATTACK	FORWARD
33	36.5	29	36.5	64	1	NO	1:3	DEFEND	REACHED
34	34.9	33	35.8	17	C	YES	1:1	WITHDRAW	REAR
35	34.5	30	36.3	61	1	NO	1:3	DELAY	FORWARD
36	34.5	36	33.3	58	1	NO	1:3	DEFEND	FORWARD
37	33.3	37	33.0	32	C	NO	1:1	DELAY	REACHED
38	32.4	43	30.5	49	1	YES	1:3	DELAY	REACHED
39	32.3	34	34.7	44	1	YES	1:1	DELAY	FORWARD
40	32.3	39	32.3	41	1	YES	1:1	DEFEND	FORWARD
41	31.1	47	27.4	35	C	NO	1:1	WITHDRAW	REAR
42	30.2	48	24.5	52	1	YES	1:3	WITHDRAW	REAR
43	28.7	42	31.5	12	C	YES	3:1	DEFEND	REACHED
44	28.5	38	32.8	59	1	NO	1:1	DEFEND	FORWARD
45	28.5	40	31.8	67	1	NO	1:3	DELAY	REACHED
46	28.5	53	20.5	62	1	NO	1:1	DELAY	FORWARD
47	28.2	56	19.8	47	1	YES	1:1	DEFEND	REACHED
48	26.7	35	33.4	6	C	YES	3:1	DEFEND	FORWARD
49	26.7	46	27.8	9	C	YES	3:1	DELAY	FORWARD
50	26.3	45	28.3	70	1	NO	1:3	WITHDRAW	REAR
51	24.8	49	24.0	70	C	NO	3:1	DEFEND	REACHED
52	24.3	51	21.5	65	1	NO	1:1	DEFEND	REACHED
53	22.8	50	22.5	24	C	NO	3:1	DEFEND	FORWARD
54	22.8	52	20.8	27	C	NO	3:1	DELAY	FORWARD
55	20.7	57	19.8	15	C	YES	3:1	DELAY	REACHED
56	20.2	54	20.3	50	1	YES	1:1	DELAY	REACHED
57	18.5	62	15.6	18	C	YES	3:1	WITHDRAW	REAR
58	18.0	59	18.4	53	1	YES	1:1	WITHDRAW	REAR
59	16.8	60	18.3	33	C	NO	3:1	DELAY	REACHED
60	16.3	58	18.8	68	1	NO	1:1	DELAY	REACHED
61	16.0	66	12.3	48	1	YES	3:1	DEFEND	REACHED
62	14.6	64	13.5	36	C	NO	3:1	WITHDRAW	REAR
63	14.1	61	17.3	71	1	NO	1:1	WITHDRAW	REAR
64	13.9	55	20.0	42	1	YES	3:1	DEFEND	FORWARD
65	13.9	67	12.0	45	1	YES	3:1	DELAY	FORWARD
66	12.1	65	12.9	66	1	NO	3:1	DEFEND	REACHED
67	10.1	63	14.3	60	1	NO	3:1	DEFEND	FORWARD
68	10.1	68	10.8	63	1	NO	3:1	DELAY	FORWARD
69	8.0	69	8.3	51	1	YES	3:1	DELAY	REACHED
70	5.8	70	8.0	54	1	YES	3:1	WITHDRAW	REAR
71	4.1	72	6.1	69	1	NO	3:1	DELAY	REACHED
72	1.9	71	6.9	72	1	NO	3:1	WITHDRAW	REAR

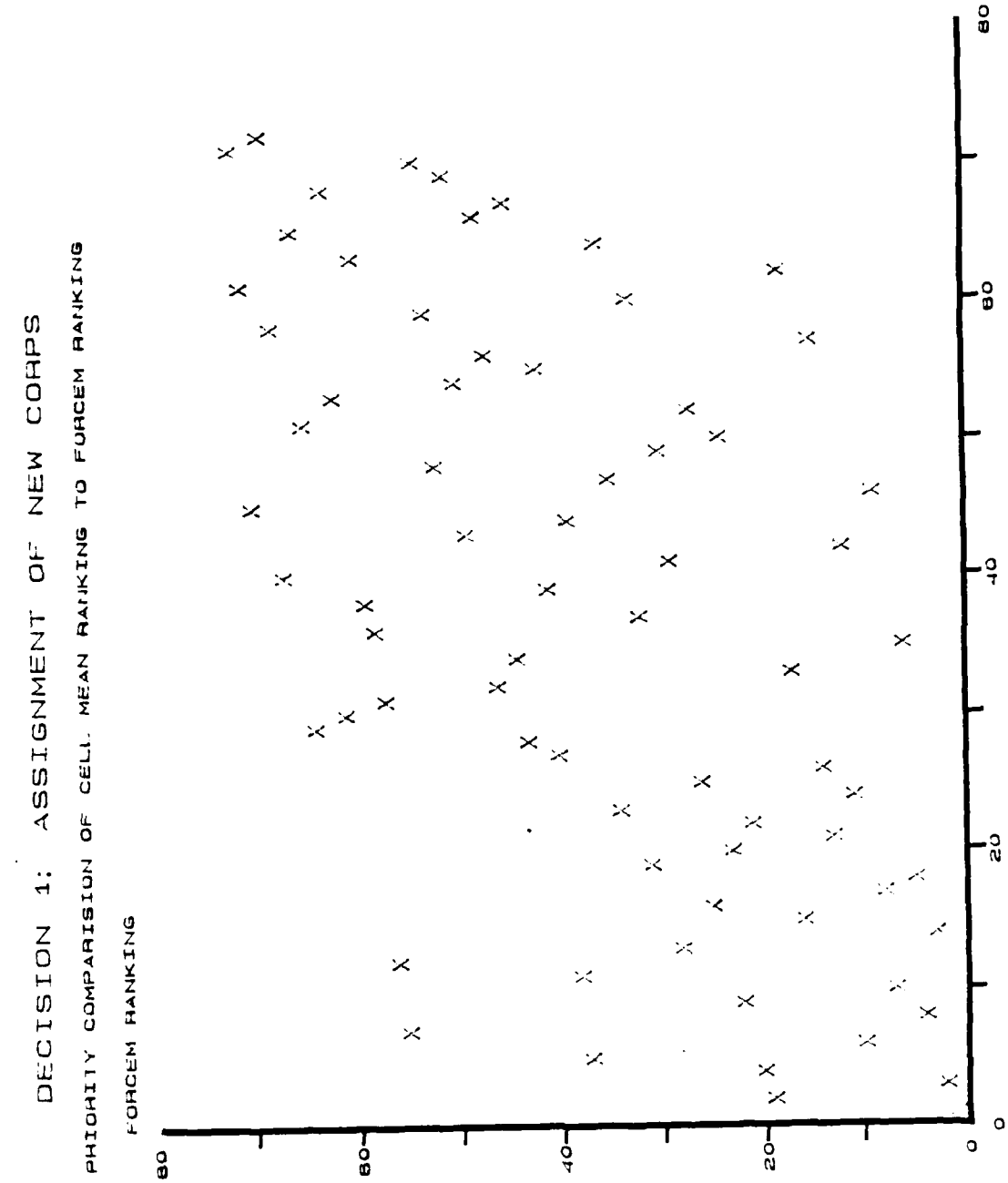
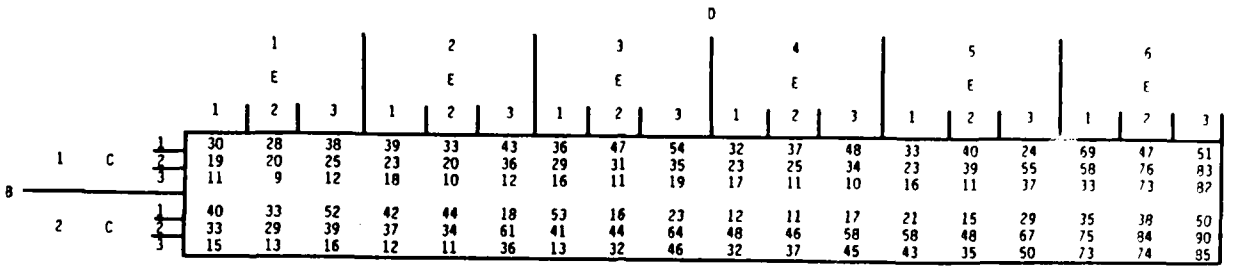


Figure I-1. Validation - Decision 1

Table I-8. Cell Means - Decision 2



B	C	E	D=1	D=2	D=3	D=4	D=5	D=6
1	1	1	30	39	36	32	33	69
		2	28	33	47	37	40	47
		3	38	43	54	48	24	51
	2	1	19	18	29	23	23	58
		2	20	20	31	25	39	76
		3	25	36	35	34	55	83
	3	1	11	18	16	17	16	33
		2	9	10	11	11	11	73
		3	12	12	19	10	37	87
2	1	1	40	42	53	12	21	35
		2	33	37	41	11	15	38
		3	52	44	44	17	29	50
	2	1	33	34	64	48	58	75
		2	29	61	44	46	48	84
		3	39	18	64	58	67	90
	3	1	15	12	23	32	43	73
		2	13	11	32	37	35	74
		3	16	36	46	45	50	85

Table I-9. Marginal Means - Decision 2

Factors	Levels					
	1	2	3	4	5	6
B	33	40				
C	35	45	30			
D	26	29	34	30	36	65
E	33	34	43			

Overall = 36.6

Table I-10. ANOVA Table - Decision 2

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Level of significance
B	1	26,685	26,685	19.4	***
C	2	80,723	40,361	31.8	***
D	5	375,844	75,169	42.0	***
E	2	42,030	21,015	7.3	**
BC	2	80,199	40,100	33.4	***
BD	5	2,139	428	1.4	
BE	2	2,328	1,164	2.1	
CD	10	105,413	10,541	19.9	***
CE	4	15,439	3,860	8.7	***
DE	10	6,975	698	2.2	*
BCD	10	32,384	3,238	7.8	***
BCE	4	2,023	506	1.1	
BDE	10	3,583	359	1.3	
CDE	20	28,240	1,412	4.4	***
BCDE	20	57,184	2,859	8.0	***
T	19	307,374	16,178	133.9	***
BT	19	26,075	1,372	11.4	***
CT	38	48,181	1,268	10.4	***
DT	95	170,030	1,790	14.8	***
ET	38	109,391	2,879	23.8	***
BCT	38	45,613	1,200	9.9	***
BDT	95	29,449	310	2.6	***
BET	38	20,653	543	4.4	***
CDT	190	100,656	530	4.4	***
CET	76	33,925	446	3.7	***
DET	190	59,100	311	2.6	***
BCDT	190	78,527	413	3.4	***
BCET	76	34,490	454	3.8	***
BDET	190	52,258	275	2.3	***
CDET	380	121,665	320	2.6	***
BCDET	380	136,616	360	3.0	***
Error	80	9,669	121		

* Significant at the 0.05 level of significance
** Significant at the 0.01 level of significance
*** Significant at the 0.001 level of significance

Table I-11. Comparison of Models - Decision 2
(page 1 of 2 pages)

REGRESSION MODEL PREDICTED VALUE AND PRIORITY		CELL MEAN CRITICAL INDEX AND PRIORITY		PRESENT FORCEM PRIORITY	ONLINE OR RESERVE	NUMBER CORPS IN RESERVE	ENGAGED	FORCE RATIO FR:EN	POSTURE	LOCATION
1	92.9	1	89.6	2	ONLINE	0	YES	1:1	ATTACK	FORWARD
2	83.7	2	84.9	3	ONLINE	0	YES	3:1	ATTACK	FORWARD
3	79.0	3	83.9	38	ONLINE	1	YES	1:1	ATTACK	FORWARD
4	79.0	7	74.9	74	RESERVE		YES	1:1	ATTACK	FORWARD
5	77.1	10	72.5	75	RESERVE		YES	3:1	ATTACK	FORWARD
6	76.9	8	73.7	39	ONLINE	1	YES	3:1	ATTACK	FORWARD
7	76.2	4	80.8	20	ONLINE	0	NO	1:1	ATTACK	FORWARD
8	74.9	5	82.0	21	ONLINE	0	NO	3:1	ATTACK	FORWARD
9	69.8	11	68.6	91	RESERVE		NO	1:3	ATTACK	FORWARD
10	69.2	9	72.5	57	ONLINE	1	NO	3:1	ATTACK	FORWARD
11	62.5	12	67.0	5	ONLINE	0	YES	1:1	DEFEND	FORWARD
12	62.5	13	64.4	11	ONLINE	0	YES	1:1	DEFEND	REACHED
13	62.3	6	75.9	56	ONLINE	1	NO	1:1	ATTACK	FORWARD
14	62.3	15	58.3	92	RESERVE		NO	1:1	ATTACK	FORWARD
15	57.8	17	58.2	8	ONLINE	0	YES	1:1	DELAY	FORWARD
16	52.5	14	61.2	14	ONLINE	0	YES	1:1	DELAY	REACHED
17	52.5	22	50.8	19	ONLINE	0	NO	1:3	ATTACK	FORWARD
18	48.6	16	58.3	77	RESERVE		YES	1:1	DEFEND	FORWARD
19	48.6	21	52.0	16	ONLINE	0	YES	1:3	WITHDRAW	REAR
20	48.6	26	47.5	41	ONLINE	1	YES	1:1	DEFEND	FORWARD
21	48.6	33	44.0	47	ONLINE	1	YES	1:1	DEFEND	REACHED
22	48.6	38	40.8	83	RESERVE		YES	1:1	DEFEND	REACHED
23	48.0	24	49.8	1	ONLINE	0	YES	1:3	ATTACK	FORWARD
24	47.5	25	48.3	25	ONLINE	0	NO	1:3	DELAY	FORWARD
25	46.5	19	54.1	28	ONLINE	0	NO	1:3	DEFEND	REACHED
26	46.1	30	46.4	12	ONLINE	0	YES	3:1	DEFEND	REACHED
27	45.7	18	54.7	23	ONLINE	0	NO	1:1	DEFEND	FORWARD
28	45.7	55	34.8	29	ONLINE	0	NO	1:1	DEFEND	REACHED
29	45.5	23	49.8	6	ONLINE	0	YES	3:1	DEFEND	FORWARD
30	45.0	42	39.0	17	ONLINE	0	YES	1:1	WITHDRAW	REAR
31	44.6	32	44.5	9	ONLINE	0	YES	3:1	DELAY	FORWARD
32	44.4	46	37.0	24	ONLINE	0	NO	3:1	DEFEND	FORWARD
33	44.1	28	47.4	55	ONLINE	1	NO	1:3	ATTACK	FORWARD
34	43.9	27	47.5	80	RESERVE		YES	1:1	DELAY	FORWARD
35	43.9	31	46.0	44	ONLINE	1	YES	1:1	DELAY	FORWARD
36	43.4	62	32.5	93	RESERVE		NO	3:1	ATTACK	FORWARD
37	43.3	35	43.3	31	ONLINE	0	NO	1:3	DELAY	REACHED
38	42.9	50	36.1	15	ONLINE	0	YES	3:1	DELAY	REACHED
39	41.6	20	52.7	82	RESERVE		YES	1:3	DEFEND	REACHED
40	41.4	45	37.5	34	ONLINE	0	NO	1:3	WITHDRAW	REAR
41	41.3	34	43.8	49	ONLINE	1	YES	1:3	DELAY	REACHED
42	41.1	56	34.3	26	ONLINE	0	NO	1:1	DELAY	FORWARD
43	40.8	44	37.8	37	ONLINE	1	YES	1:3	ATTACK	FORWARD
44	40.5	54	35.3	73	RESERVE		YES	1:3	ATTACK	FORWARD
45	39.9	53	35.3	42	ONLINE	1	YES	3:1	DEFEND	FORWARD
46	39.4	29	47.3	64	ONLINE	1	NO	1:3	DEFEND	REACHED
47	39.4	40	39.8	58	ONLINE	1	NO	1:3	DEFEND	FORWARD
48	39.4	52	35.5	100	RESERVE		NO	1:3	DEFEND	REACHED
49	39.4	58	33.3	94	RESERVE		NO	1:3	DEFEND	FORWARD
50	38.9	36	42.7	78	RESERVE		YES	3:1	DEFEND	FORWARD

Table I-11. Comparison of Models - Decision 2
(page 2 of 2 pages)

51	38.6	48	36.5	86	RESERVE		YES	1:1	DELAY	REACHED
52	38.6	57	33.5	50	ONLINE	1	YES	1:1	DELAY	REACHED
53	38.4	37	41.6	85	RESERVE		YES	1:3	DELAY	REACHED
54	36.5	39	39.8	88	RESERVE		YES	1:3	WITHDRAW	REAR
55	36.5	63	32.3	48	ONLINE	1	YES	3:1	DEFEND	REACHED
56	36.2	43	38.9	103	RESERVE		NO	1:3	DELAY	REACHED
57	36.2	59	33.0	67	ONLINE	1	NO	1:3	DELAY	REACHED
58	35.8	51	35.8	32	ONLINE	0	NO	1:1	DELAY	REACHED
59	35.3	49	36.5	45	ONLINE	1	YES	3:1	DELAY	FORWARD
60	34.7	47	36.9	61	ONLINE	1	NO	1:3	DELAY	FORWARD
61	34.7	64	32.0	97	RESERVE		NO	1:3	DELAY	FORWARD
62	34.3	67	30.0	106	RESERVE		NO	1:3	WITHDRAW	REAR
63	34.3	71	28.1	70	ONLINE	1	NO	1:3	WITHDRAW	REAR
64	34.2	65	31.8	81	RESERVE		YES	3:1	DELAY	FORWARD
65	32.8	60	32.5	52	ONLINE	1	YES	1:3	WITHDRAW	REAR
66	31.8	41	39.2	59	ONLINE	1	NO	1:1	DEFEND	FORWARD
67	31.8	66	30.8	65	ONLINE	1	NO	1:1	DEFEND	REACHED
68	31.8	70	28.5	101	RESERVE		NO	1:1	DEFEND	REACHED
69	31.8	75	22.8	95	RESERVE		NO	1:1	DEFEND	FORWARD
70	31.1	61	32.5	89	RESERVE		YES	1:1	WITHDRAW	REAR
71	31.1	69	28.9	53	ONLINE	1	YES	1:1	WITHDRAW	REAR
72	28.3	73	25.1	35	ONLINE	0	NO	1:1	WITHDRAW	REAR
73	27.2	72	25.2	62	ONLINE	1	NO	1:1	DELAY	FORWARD
74	27.2	76	22.6	98	RESERVE		NO	1:1	DELAY	FORWARD
75	25.3	68	29.0	4	ONLINE	0	YES	1:3	DEFEND	FORWARD
76	24.8	78	22.5	10	ONLINE	0	YES	1:3	DEFEND	REACHED
77	22.0	74	23.9	22	ONLINE	0	NO	1:3	DEFEND	FORWARD
78	21.9	77	22.6	104	RESERVE		NO	1:1	DELAY	REACHED
79	21.9	81	20.0	68	ONLINE	1	NO	1:1	DELAY	REACHED
80	21.6	85	17.5	13	ONLINE	0	YES	1:3	DELAY	REACHED
81	20.2	88	16.0	46	ONLINE	1	YES	1:3	DEFEND	REACHED
82	20.0	82	19.3	30	ONLINE	0	NO	3:1	DEFEND	REACHED
83	17.8	79	20.7	76	RESERVE		YES	1:3	DEFEND	FORWARD
84	16.9	87	16.8	7	ONLINE	0	YES	1:3	DELAY	FORWARD
85	16.8	92	14.9	40	ONLINE	1	YES	1:3	DEFEND	FORWARD
86	16.8	97	12.3	33	ONLINE	0	NO	3:1	DELAY	REACHED
87	15.1	95	12.5	84	RESERVE		YES	3:1	DEFEND	REACHED
88	15.0	99	11.5	36	ONLINE	0	NO	3:1	WITHDRAW	REAR
89	14.4	80	20.2	71	ONLINE	1	NO	1:1	WITHDRAW	REAR
90	14.4	83	18.9	107	RESERVE		NO	1:1	WITHDRAW	REAR
91	13.7	94	13.4	54	ONLINE	1	YES	3:1	WITHDRAW	REAR
92	13.2	96	12.3	79	RESERVE		YES	1:3	DELAY	FORWARD
93	13.0	89	15.7	102	RESERVE		NO	3:1	DEFEND	REACHED
94	13.0	90	15.6	96	RESERVE		NO	3:1	DEFEND	FORWARD
95	13.0	101	10.9	66	ONLINE	1	NO	3:1	DEFEND	REACHED
96	13.0	103	10.8	60	ONLINE	1	NO	3:1	DEFEND	FORWARD
97	12.1	91	15.5	18	ONLINE	0	YES	3:1	WITHDRAW	REAR
98	12.1	104	10.6	43	ONLINE	1	YES	1:3	DELAY	FORWARD
99	11.9	98	13.2	87	RESERVE		YES	3:1	DELAY	REACHED
100	10.1	93	14.8	90	RESERVE		YES	3:1	WITHDRAW	REAR
101	9.8	84	17.6	105	RESERVE		NO	3:1	DELAY	REACHED
102	9.8	107	9.9	69	ONLINE	1	NO	3:1	DELAY	REACHED
103	9.7	106	10.4	27	ONLINE	0	NO	3:1	DELAY	FORWARD
104	9.0	100	11.4	51	ONLINE	1	YES	3:1	DELAY	REACHED
105	8.3	86	17.0	99	RESERVE		NO	3:1	DELAY	FORWARD
106	8.3	102	10.8	63	ONLINE	1	NO	3:1	DELAY	FORWARD
107	7.9	105	10.5	108	RESERVE		NO	3:1	WITHDRAW	REAR
108	7.9	108	9.3	72	ONLINE	1	NO	3:1	WITHDRAW	REAR

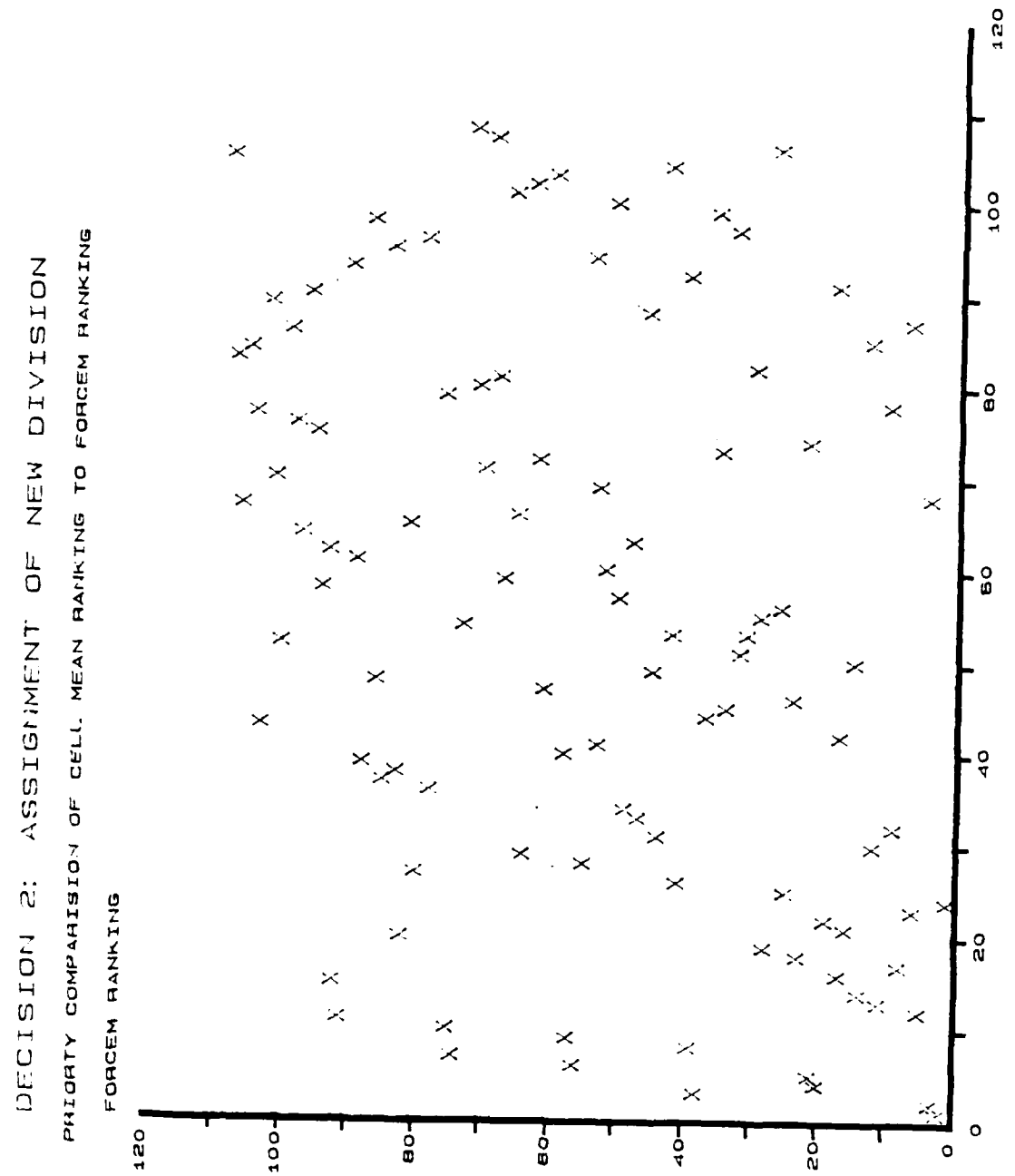


Figure I-2. Validation - Decision 2

Table I-12. Cell Means - Decision 3

				F = 1, G = 1	F = 1, G = 2	F = 2, G = 1	F = 2, G = 2
B	1	D	1	40	26	53	38
			2	45	33	62	45
			3	52	35	58	48
			4	46	40	55	46
			5	46	36	57	52
			6	48	47	71	57
	2	D	1	71	58	76	69
			2	72	64	87	68
			3	77	63	87	69
			4	69	64	77	64
			5	71	66	80	68
			6	78	68	86	76

Table I-13. Marginal Means - Decision 3

Factors	Levels					
	1	2	3	4	5	6
B	47	72				
D	54	59	61	58	59	66
F	55	65				
G	65	54				

Overall = 59.6

Table I-14. ANOVA Table - Decision 3

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Level of significance
B	1	148,305	148,305	89.5	***
D	5	13,625	2,725	6.9	***
F	1	23,364	23,364	19.1	***
G	1	28,777	28,777	33.2	***
BD	5	1,874	375	1.2	
BF	1	1,426	1,426	3.2	
BG	1	15	15	<1.0	
DF	5	1,061	212	1.3	
DG	5	2,034	407	2.4	*
FG	1	398	398	1.3	
BDF	5	344	69	<1.0	
BDG	5	340	68	<1.0	
BFG	1	84	84	<1.0	
DFG	5	934	187	<1.0	
BDFG	5	1,228	246	1.8	
T	19	264,372	13,914	83.0	***
BT	19	31,492	1,657	9.9	***
DT	95	37,411	394	2.3	***
FT	19	23,277	1,225	7.3	***
GT	19	16,457	866	5.2	***
BDT	95	30,786	324	1.9	***
BFT	19	8,606	453	2.7	***
BGT	19	5,500	289	1.7	*
DFT	95	15,174	160	<1.0	
DGT	95	15,979	168	<1.0	
FGT	19	5,740	302	1.8	*
BDFT	95	14,901	157	<1.0	
BDGT	95	17,985	189	1.1	
BFGT	19	5,539	292	1.7	*
BFGT	95	13,809	198	1.2	
BDFGT	95	13,090	138	<1.0	
Error	30	13,419	168		

* Significant at the 0.05 level of significance
*** Significant at the 0.001 level of significance

Table I-15. Comparison of Models - Decision 3

REGRESSION MODEL PREDICTED VALUE AND PRIORITY	CELL MEAN CRITICAL INDEX AND PRIORITY	PRESENT FORCEM PRIORITY	ONLINE OR RESERVE	ENGAGED	RATIO ARTY UNITS TO DIVISIONS	POSTURE	LOCATION LOCATION
1 86.0	3 86.4	1	ONLINE	YES	0.25	ATTACK	FORWARD
2 84.6	1 87.4	7	ONLINE	YES	0.25	DELAY	REACHED
3 84.6	2 86.9	7	ONLINE	YES	0.25	DEFEND	REACHED
4 81.0	5 78.1	25	RESERVE	YES	0.25	ATTACK	FORWARD
5 78.3	9 76.3	11	ONLINE	YES	0.25	WITHDRAW	REAR
6 78.2	4 79.7	1	ONLINE	YES	0.25	DEFEND	FORWARD
7 78.2	7 77.1	1	ONLINE	YES	0.25	DELAY	FORWARD
8 75.1	8 76.3	4	ONLINE	YES	1.00	ATTACK	FORWARD
9 73.7	15 69.3	9	ONLINE	YES	1.00	DEFEND	REACHED
10 73.7	19 67.9	9	ONLINE	YES	1.00	DELAY	REACHED
11 73.2	6 77.4	31	RESERVE	YES	0.25	DEFEND	REACHED
12 73.2	10 72.3	31	RESERVE	YES	0.25	DELAY	REACHED
13 73.2	12 70.5	25	RESERVE	YES	0.25	DEFEND	FORWARD
14 73.2	16 68.8	25	RESERVE	YES	0.25	DELAY	FORWARD
15 70.0	17 68.3	28	RESERVE	YES	1.00	ATTACK	FORWARD
16 67.4	14 69.4	12	ONLINE	YES	1.00	WITHDRAW	REAR
17 67.3	18 68.3	4	ONLINE	YES	1.00	DEFEND	FORWARD
18 67.3	21 64.4	4	ONLINE	YES	1.00	DELAY	FORWARD
19 66.9	11 71.0	35	RESERVE	YES	0.25	WITHDRAW	REAR
20 66.0	13 70.5	13	ONLINE	NO	0.25	ATTACK	FORWARD
21 62.2	20 65.8	28	RESERVE	YES	1.00	DEFEND	FORWARD
22 62.2	22 63.8	28	RESERVE	YES	1.00	DELAY	FORWARD
23 62.2	23 63.8	33	RESERVE	YES	1.00	DELAY	REACHED
24 62.2	24 62.6	33	RESERVE	YES	1.00	DEFEND	REACHED
25 58.2	25 61.5	19	ONLINE	NO	0.25	DELAY	REACHED
26 58.2	27 57.9	19	ONLINE	NO	0.25	DEFEND	REACHED
27 58.2	29 56.8	13	ONLINE	NO	0.25	DEFEND	FORWARD
28 58.2	30 55.0	13	ONLINE	NO	0.25	DELAY	FORWARD
29 55.9	26 58.0	36	RESERVE	YES	1.00	WITHDRAW	REAR
30 55.0	28 57.3	16	ONLINE	NO	1.00	ATTACK	FORWARD
31 54.5	35 47.5	37	RESERVE	NO	0.25	ATTACK	FORWARD
32 51.9	31 52.8	23	ONLINE	NO	0.25	WITHDRAW	REAR
33 47.2	33 51.7	16	ONLINE	NO	1.00	DEFEND	FORWARD
34 47.2	34 48.0	21	ONLINE	NO	1.00	DEFEND	REACHED
35 47.2	38 46.0	16	ONLINE	NO	1.00	DELAY	FORWARD
36 47.2	41 45.0	21	ONLINE	NO	1.00	DELAY	REACHED
37 46.7	32 52.1	43	RESERVE	NO	0.25	DEFEND	REACHED
38 46.7	37 46.3	37	RESERVE	NO	0.25	DEFEND	FORWARD
39 46.7	39 45.8	37	RESERVE	NO	0.25	DELAY	FORWARD
40 46.7	40 45.3	43	RESERVE	NO	0.25	DELAY	REACHED
41 43.5	36 46.8	40	RESERVE	NO	1.00	ATTACK	FORWARD
42 40.9	44 38.0	24	ONLINE	NO	1.00	WITHDRAW	REAR
43 40.4	42 39.5	47	RESERVE	NO	0.25	WITHDRAW	REAR
44 35.8	43 39.5	40	RESERVE	NO	1.00	DELAY	FORWARD
45 35.8	45 36.3	40	RESERVE	NO	1.00	DEFEND	FORWARD
46 35.8	46 35.0	45	RESERVE	NO	1.00	DEFEND	REACHED
47 35.8	47 32.5	45	RESERVE	NO	1.00	DELAY	REACHED
48 29.5	48 26.3	48	RESERVE	NO	1.00	WITHDRAW	REAR

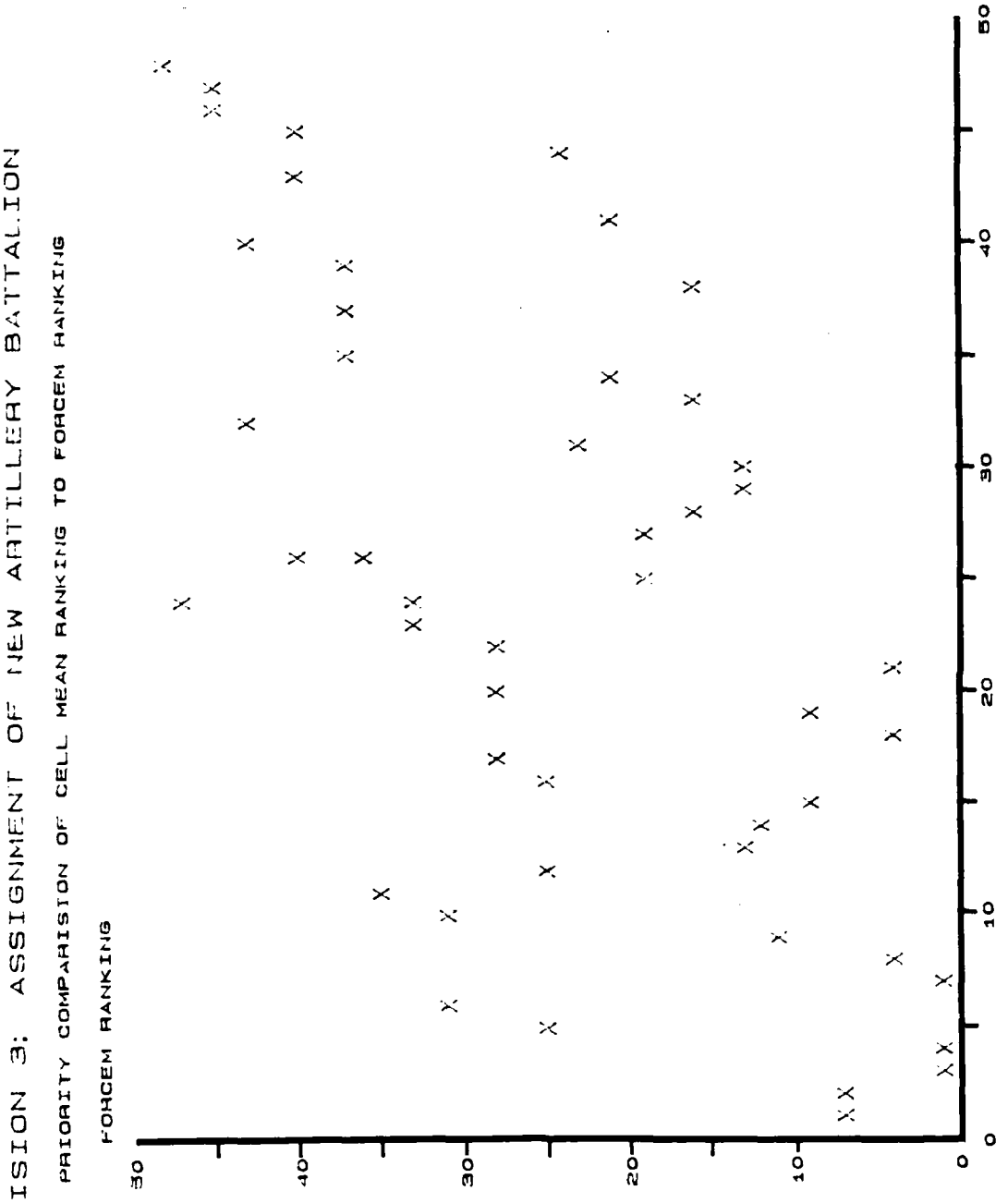


Figure I-3. Validation - Decision 3

Table I-16. Cell Means - Decision 5

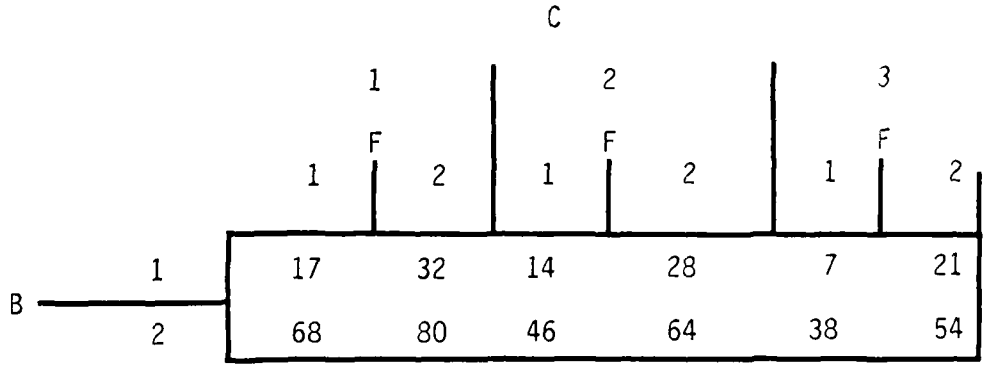


Table I-17. Marginal Means - Decision 5

Factors	Levels					
	1	2	3	4	5	6
B	20	58				
C	49	38	30			
F	32	47				

Overall = 39.1

Table I-18. ANOVA Table - Decision 5

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Level of significance
B	1	93,497	93,497	85.8	***
C	2	16,036	8,018	36.0	***
F	1	14,055	14,055	33.5	***
BC	2	4,014	2,012	15.6	***
BF	1	10	10	<1.0	
CF	2	60	30	<1.0	
BCF	2	166	83	<1.0	
T	20	68,956	3,448	57.2	***
BT	20	21,791	1,090	18.1	***
CT	40	8,903	223	3.7	***
FT	20	8,395	420	7.0	***
BCT	40	5,161	129	2.1	***
BFT	20	3,817	191	3.2	***
CFT	40	3,473	87	1.4	
BCFT	40	6,310	158	2.6	***
Error	84	5,063	60		

*** Significant at the 0.001 level of significance

Table I-19. Comparison of Models - Decision 5

REGRESSION MODEL PREDICTED VALUE AND PRIORITY	CELL MEAN CRITICAL INDEX AND PRIORITY	ENGAGED	FORCE RATIO FR:EN	ECHELON
1 79.9	1 80.3	YES	1:3	ONLINE
2 65.8	3 63.9	YES	1:1	ONLINE
3 65.0	2 68.3	YES	1:3	RESERVE
4 51.6	4 53.8	YES	3:1	ONLINE
5 50.8	5 45.6	YES	1:1	RESERVE
6 36.7	6 38.1	YES	3:1	RESERVE
7 32.5	7 32.3	NO	1:3	ONLINE
8 27.2	8 27.7	NO	1:1	ONLINE
9 22.0	9 21.3	NO	3:1	ONLINE
10 17.5	10 16.9	NO	1:3	RESERVE
11 12.3	11 13.9	NO	1:1	RESERVE
12 7.1	12 7.0	NO	3:1	RESERVE

Table I-20. Cell Means - Decision 6

		C = 1		C = 2		C = 3	
		F = 1	F = 2	F = 1	F = 2	F = 1	F = 2
B	1	36	59	30	49	21	47
	2	69	87	57	70	52	62

Table I-21. Margin Means - Decision 6

Factors	Levels 1	2	3	4	5	6
B	40	66				
C	62	52	45			
F	44	62				

Overall = 53.0

Table I-22. ANOVA Table - Decision 6

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Level of significance
B	1	41,760	41,760	75.4	***
C	2	12,413	6,206	28.9	***
F	1	20,520	20,520	51.4	***
BC	2	648	324	2.5	
BF	1	1,467	1,467	6.1	*
CF	2	113	57	<1.0	
BCF	2	347	173	<1.0	
T	20	61,268	3,063	25.8	***
BT	20	11,073	554	4.7	***
CT	40	8,596	215	1.8	*
FT	20	7,993	400	3.4	***
BCT	40	5,245	141	1.1	
BFT	20	4,848	242	2.0	*
CFT	40	3,546	89	<1.0	
BCFT	40	7,427	186	1.6	*
Error	84	9,981	119		

* Significant at the 0.05 level of significance
*** Significant at the 0.001 level of significance

Table I-23. Comparison of Models - Decision 6

REGRESSION MODEL PREDICTED VALUE AND PRIORITY	CELL MEAN CRITICAL INDEX AND PRIORITY	ENGAGED	FORCE RATIO FR:EN	ECHELON
1 83.4	1 85.6	YES	1:3	ONLINE
2 74.9	2 70.2	YES	1:1	ONLINE
3 66.4	4 61.7	YES	3:1	ONLINE
4 65.3	3 69.1	YES	1:3	RESERVE
5 57.6	5 58.6	NO	1:3	ONLINE
6 56.8	6 56.9	YES	1:1	RESERVE
7 49.1	8 49.3	NO	1:1	ONLINE
8 48.3	7 51.8	YES	3:1	RESERVE
9 40.6	9 46.9	NO	3:1	ONLINE
10 39.6	10 35.7	NO	1:3	RESERVE
11 31.1	11 29.8	NO	1:1	RESERVE
12 22.6	12 20.7	NO	3:1	RESERVE

Table I-24. Cell Means - Decision 7

		R								
		1			2			3		
		S			S			S		
		1	2	3	1	2	3	1	2	3
P	1	44	29	17	42	23	14	35	21	9
	2	88	73	71	73	61	50	52	47	37

Table I-25. Marginal Means - Decision 7

	Levels					
Factors	1	2	3	4	5	6
P	26	61				
R	54	44	33			
S	56	42	33			

Overall = 43.5

Table I-26. ANOVA Table - Decision 7

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Level of significance
P	1	111,443	111,443	109.7	***
R	2	24,483	12,241	32.3	***
S	2	30,992	15,496	25.1	***
PR	2	8,367	4,183	20.0	***
PS	2	1,252	626	3.2	*
RS	4	514	128	1.2	
PRS	4	451	113	<1.0	
T	19	32,029	1,686	15.8	***
PT	19	19,302	1,016	9.5	***
RT	38	14,384	379	3.5	***
ST	38	23,459	617	5.8	***
PRT	38	7,956	209	2.0	**
PST	38	7,329	193	1.8	*
RST	76	8,285	109	<1.0	
PRST	76	11,579	152	1.4	
Error	80	8,553	107		

* Significant at the 0.05 level of significance
** Significant at the 0.01 level of significance
*** Significant at the 0.001 level of significance

Table I-27. Comparison of Models - Decision 7

REGRESSION MODEL PREDICTED VALUE AND PRIORITY	CELL MEAN CRITICAL INDEX AND PRIORITY	ENGAGED	FORCE RATIO FR:EN	ECHELON
1 89.1	1 87.8	YES	1:3	FIRST
2 75.8	2 73.3	YES	1:3	SECOND
3 73.1	3 72.5	YES	1:1	FIRST
4 66.5	4 70.8	YES	1:3	THIRD
5 59.8	5 60.5	YES	1:1	SECOND
6 57.1	6 51.8	YES	3:1	FIRST
7 50.5	7 49.8	YES	1:1	THIRD
8 43.8	8 46.8	YES	3:1	SECOND
9 42.1	9 43.8	NO	1:3	FIRST
10 37.9	10 42.0	NO	1:1	FIRST
11 34.5	11 37.3	YES	3:1	THIRD
12 33.7	12 35.3	NO	3:1	FIRST
13 28.9	13 29.3	NO	1:3	SECOND
14 24.7	14 23.0	NO	1:1	SECOND
15 20.5	15 20.8	NO	3:1	SECOND
16 19.5	16 17.0	NO	1:3	THIRD
17 15.3	17 13.8	NO	1:1	THIRD
18 11.1	18 8.8	NO	3:1	THIRD

Table I-28. Cell Means - Decision 8

		R = 1, S = 1			R = 2, S = 1			R = 3, S = 1		
		1	2	3	1	2	3	1	2	3
P	1	57	42	33	50	35	26	41	28	25
	2	88	78	73	71	65	66	65	55	56

Table I-29. Marginal Means - Decision 8

Factors	Levels					
	1	2	3	4	5	6
P	37	69				
R	62	52	45			
S	62	50	46			

Overall = 52.9

Table I-30. ANOVA Table - Decision 8

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Level of significance
P	1	88,454	88,454	73.0	***
R	2	16,802	8,401	18.9	***
S	2	15,682	7,841	12.6	***
PR	2	1,102	551	2.4	
PS	2	1,972	986	6.0	***
RS	4	673	168	1.1	
PRS	4	385	96	<1.0	
T	19	60,233	3,170	8.6	***
PT	19	23,038	1,213	3.3	***
RT	38	16,862	444	1.2	
ST	38	23,613	621	1.7	*
PRT	38	8,698	229	<1.0	
PST	38	6,227	164	<1.0	
RST	76	11,927	157	<1.0	
PRST	76	13,096	172	<1.0	
Error	80	29,399	367		

* Significant at the 0.05 level of significance
*** Significant at the 0.001 level of significance

Table I-31. Comparison of Models - Decision 8

REGRESSION MODEL PREDICTED VALUE AND PRIORITY	CELL MEAN CRITICAL INDEX AND PRIORITY	ENGAGED	FORCE RATIO FRIEN	ECHELON
1 95.9	1 87.8	YES	1:3	FIRST
2 77.6	4 71.1	YES	1:1	FIRST
3 72.4	2 78.3	YES	1:3	SECOND
3 72.4	3 72.8	YES	1:3	THIRD
5 69.2	6 65.3	YES	3:1	FIRST
6 64.0	5 65.8	YES	1:1	THIRD
6 64.0	7 65.2	YES	1:1	SECOND
8 55.7	9 56.0	YES	3:1	THIRD
8 55.7	10 54.8	YES	3:1	SECOND
8 54.5	8 56.5	NO	1:3	FIRST
11 46.2	11 49.5	NO	1:1	FIRST
12 41.0	12 42.0	NO	1:3	SECOND
12 41.0	15 32.5	NO	1:3	THIRD
14 37.8	13 41.2	NO	3:1	FIRST
15 32.7	14 34.8	NO	1:1	SECOND
15 32.7	17 25.6	NO	1:1	THIRD
17 24.3	16 27.5	NO	3:1	SECOND
17 24.3	18 25.0	NO	3:1	THIRD

APPENDIX J

SHORTCOMINGS OF FORCEM C^2

J-1. INTRODUCTION. In their written comments, the subjects in the experiment suggest (explicitly or implicitly) shortcomings in the representation of C^2 in FORCEM. So also do Red experts through discussions. Such suggestions have been compiled here, rephrased in FORCEM terminology.

J-2. READILY FIXED. The concepts listed here could be accommodated without major revisions to FORCEM.

a. Contingent Change in Posture. FORCEM should allow for a change in posture "contingent" on the situation, e.g., a unit would switch from defending to attacking when superiority was gained. Such logic already exists at the corps and division levels. At the army level, logic could be introduced to transition between master plans when the situation dictates.

b. Holding Arriving Division. When a new division arrives into the theater and is not assigned by the user to a specific corps, then logic internal to the model does so. There should be the capability for the HQ making the decision (the theater or Army HQ) to delay the assignment, and thereby maintain a reserve. (See also paragraph J-3g below.)

c. Echelon at Which Decision Made. Within FORCEM, the decisions on corps type of operation and corps organization for combat are made by the corps itself. These decisions should be made by the parent army, at least for Red. This affects the timing of the decisions as well as how they are implemented.

d. Artillery Support. Army-level field artillery and surface-to-surface missiles should be capable of being assigned in support of subordinate corps. This cannot be done at present. Incorporating the capability would require additions to both the C^2 module and the fire support module.

J-3. BEYOND SCOPE OF CURRENT FORCEM. The concepts listed here cannot be incorporated into FORCEM without major overhaul to its structure.

a. AirLand Battle. Some of the aspects of AirLand Battle are not portrayed in FORCEM; e.g., deep attack by ground forces, deep attack by airmobile troops, and cutting lines of communication.

b. Personnel Issues. FORCEM does not consider personnel issues such as morale and leadership. These can only be treated implicitly by seeking division-level combat samples with various levels of such variables.

c. Time in Combat and Rate of Loss. FORCEM does not consider the effect of time in combat, or rate of attrition due to combat, on the

results of combat. Again, the only hope for treating these concepts in FORCEM is to seek division-level combat samples for various levels of the variables. If such samples could be made available, then it would be appropriate to install perception data base variables for the variables (see, e.g., Appendix K, paragraphs K-2 through K-5), and to develop logic for the FORCEM C^2 module to take account of levels associated with the perception data base variables (e.g., a division in combat for a "long" period time would be a candidate for pulling off-line).

d. Breakthrough. A breakthrough can occur, but the attacker does not take advantage of it and the defender does not attempt to compensate. There is no logic or algorithm for dealing with the situation of a division being in the enemy's rear where combat service support (CSS) units could easily be destroyed. Nor is there logic for the defending force attempting to shut off a penetration or to cut the lines of communication of the penetrator.

e. Weather. The only consideration of weather currently is day versus night, which may affect the selection of the division combat sample used in assessing division-level combat outcomes, and which does affect the numbers of aircraft sorties (by aircraft type). If FORCEM is to be used over a time period covering 180 days, then the effects of seasonal weather on combat and movement ought to be considered; e.g., rainy seasons, sub-zero temperatures.

f. Overall Consideration of Time. FORCEM takes little account of time. When an objective is set for a division, there is no time limit associated with reaching the objective. Similarly, when the control phase lines of a corps are moved, there is no time limit associated with first echelon divisions reaching the forward control phase line. At the army level, there is the capability, not yet used, to transition between master plans (and hence revise the army objective phase line) based on time or on the geographical locations of subordinate online corps'; however, even this logic would require expansion to allow for revising the army objective phase line based on a combination of time and geographical locations (e.g., if the current objective phase line is not reached by a specified time, then transition to a new master plan with a new objective phase line).

g. Combat Reserves. FORCEM should have greater flexibility in maintaining combat reserves. At the corps level, the current approach is satisfactory; here divisions can be assigned to the "second echelon," and thus be ready for combat but not committed. At higher levels, however, the only capability of this sort is for reserve corps within an army, and even here a reserve corps must be placed behind a specific online corps and can only be committed to help that online corps or one of its two immediate neighbors. There is no other mechanism for maintaining a reserve corps under an army HQ. Nor are there mechanisms for an army HQ maintaining a reserve division, or for a theater HQ maintaining a reserve division or corps or army. Furthermore, at the tneater or army level, there is no capability for reconstituting a reserve. (See also paragraph J-2b above.)

h. OPORDER Methodology. The operations order (OPORDER) methodology in FORCEM requires considerable expansion to allow for full treatment of Red concepts. The OPORDER for a corps specified by the parent army should designate time and space objectives (see paragraph J-3f above), assigned echelon, time and distance for commitment (if second echelon), whether the corps is on the primary or secondary axis of advance, and specified exchange loss rates. Specifying such parameters would necessitate additional logic at the army level for making the associated decisions and for transitioning to new OPORDERs should conditions fail to be met. Similar comments apply to an army OPORDER specified by the theater, especially for time and space objectives, assigned echelon, and time and distance for commitment. There are rudimentary capabilities for dealing with such concepts in army-level OPORDERs through user-defined MASTER PLANs, but they put a heavy burden on the user and require iterative executions of the model to obtain realistic outcomes.

APPENDIX K

ADDITIONAL PERCEPTION DATA BASE VARIABLES

K-1. INTRODUCTION. In their written comments, the subjects in the experiments suggest several variables for use as decision criteria that are not currently in the FORCEM perception data base. This appendix lists such variables, and describes how they might be computed within FORCEM. Their incorporation into the FORCEM perception data base would make them available for use in making C^2 decisions.

K-2. RATE OF LOSS FOR FRIENDLY FORCES. This variable would apply to a corps or division. The value could be absolute, relative to current onhand, or relative to authorized. The value could be computed based on losses of "onhand combat worth", which incorporates the input "global importances" of onhand combat vehicles, modified by the availability of personnel to crew the vehicles and by the availability of POL and ammunition for use by the vehicles.

K-3. RATE OF LOSS FOR ENEMY FORCES. This variable would apply to a corps or division. The value could be absolute, relative to current onhand, or relative to authorized. The value could be computed based on losses of "onhand combat worth" to opposing enemy divisions. A derivative of this variable and the previous variable would be combat momentum, taken as the ratio of losses of enemy forces to the rate of losses of friendly forces.

K-4. TIME IN SUSTAINED COMBAT FOR FRIENDLY FORCES. This variable would apply to a corps or division.

K-5. TIME IN SUSTAINED COMBAT FOR ENEMY FORCES. This variable would apply to a corps or division.

K-6. GEOGRAPHICAL MOMENTUM. This variable would apply to a corps or division, and could be taken as the rate of gain or loss of terrain.

K-7. PROJECTED RATE OF MOVEMENT. This variable would apply to a corps or division, and would consider basic movement rates, modified by terrain, congestion, POL shortage, and combat. The value could be obtained by smoothing actual movement rates of recent time cycles, modified to consider the numbers of units projected to be in the area.

K-8. NUMBER OF DIVISION THAT CAN BE PLACED IN AREA. This variable would apply to a corps, and would be expressed as the number of divisions that can be placed across the corps front considering the length of the frontage, the type of terrain, and the types of divisions.

K-9. STATUS OF ARTILLERY SUPPORT. This variable would apply to a corps or division. For a corps, it would be taken as the number of corps-level (plus, perhaps, division-level) artillery tubes available. For a division, it would be taken as the number of division-level (plus, perhaps, direct support corps-level, estimated from previous time cycles) artillery tubes available.

K-10. STATUS OF CLOSE AIR SUPPORT (CAS). This variable would apply to a corps or division, and would be taken as the ratio of the number of CAS sorties available to the number required (the latter based on model inputs), smoothed over recent time cycles.

K-11. CONTROL OF AIR. This variable would apply to the theater HQ (and possibly an army HQ), and be based on friendly air sorties versus enemy air sorties, by air role, smoothed over recent time cycles.

K-12. ENEMY POSTURE. This variable would apply to a corps or division, and be measured by considering enemy divisions in the area and determining their direction of intended movement (either by examining objectives or by smoothing recent movement).

APPENDIX L

EXPANDED CRITERIA FOR DECISIONS

L-1. INTRODUCTION. In their written comments, the subjects in the experiments suggest the use of additional decision criteria in making specific decisions. This appendix lists existing perception data base variables suggested for use in expanded rules for existing decisions to add realism. The format here is decision, followed by a list of perception data base variables to be used as decision criteria for that decision over and above the variables used in the rules currently in FORCEM.

L-2. ASSIGNMENT IF NEW FIELD ARTILLERY BATTALION

a. Posture of Potential Receiving Corps

b. Status of Divisional Field Artillery. This would include all field artillery in divisions subordinate to a potential receiving corps.

L-3. DESIGNATION OF POSTURE OF ONLINE CORPS

a. Terrain. For example, mountainous terrain favors defend over attack.

b. CSS Status of Associated Corps Support Complex

c. Information on Neighboring Online Corps. This would include, for example, engagement status, location relative to the Army objective phase line, force ratio, as well as the information in paragraphs L-3a and L-3b above.

L-4. PRIORITY TO CORPS (OR DIVISION) FOR CAS

a. Posture of Corps (or Division)

b. Adequacy of Recent CAS Support. Caution must be exercised in using this variable, lest high priority for CAS priority "ping pong" among corps' (or divisions) with the same parent. (See also Appendix K, paragraph K-10.)

L-5. PRIORITY TO CORPS (OR DIVISION) FOR CSS

a. Posture of Corps (or Division)

b. Current CSS Status. This means the CSS status of the associated corps support complex (or of the division and the associated division support complex). Just as for priority for CAS, caution must be exercised in using this variable.

c. Current Fractional Combat Worth. In the case of a corps, th.s would be accumulated across all subordinate divisions; in the case of a division, it would be for the unit itself. Here "combat worth" means the sum of the input "global importances" of onhand combat vehicles, modified by the availability of personnel to crew the vehicles and by the availability of POL and ammunition for use by the vehicles. "Fractional combat worth" means the ratio of the current combat worth to the "authorized combat worth," the latter being the sum of the global importances of the authorized combat vehicles.

APPENDIX M

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